SYNTHESISED AF GENERATOR

INFRA-RED HEADPHONES

MODERN TV RECEIVERS

POLYWHATSIT EFFECTS CONTROL
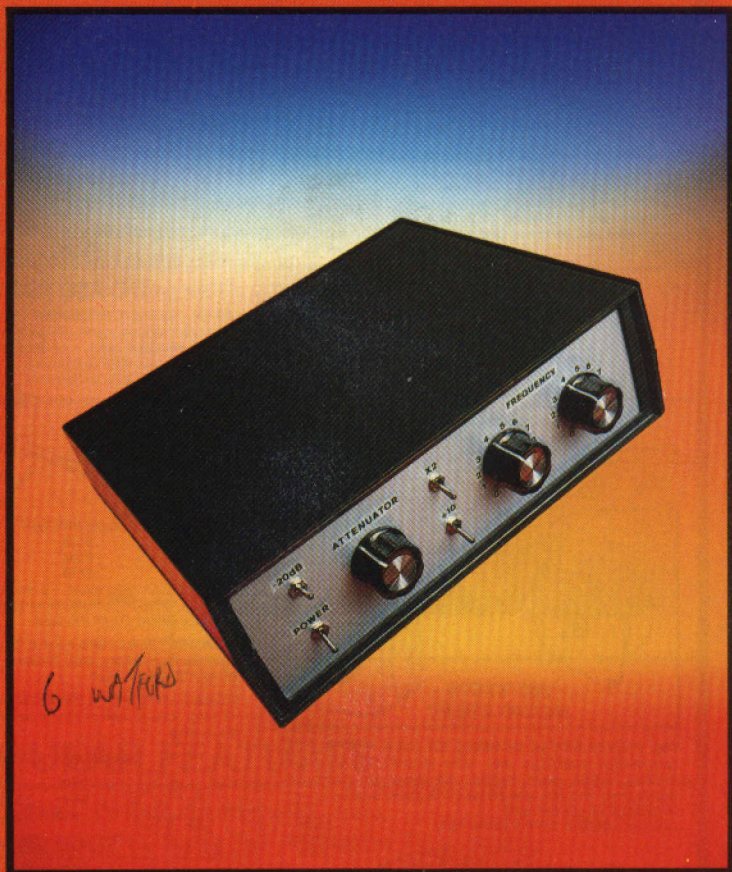
DESIGN – FREQUENCY
SYNTHESISERS THEORY AND PRACTICE

COMPUTING – ZX SPECTRUM
TWO CIRCUITS FOR EXTRA PORTS

TECHNOLOGY – SATELLITE
TV SCRAMBLING PROSPECTS

EXPERIMENTAL ELECTRONICS
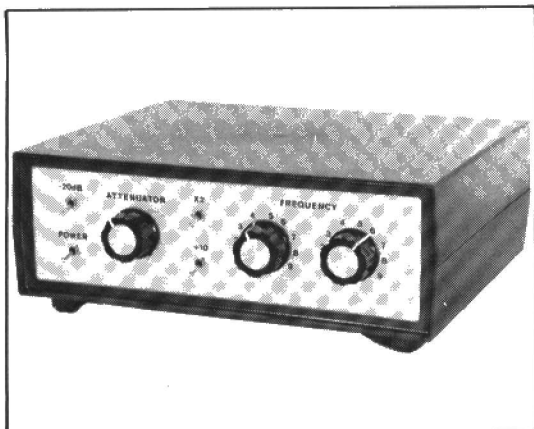EXCITING DESIGN IDEAS & PRACTICAL APPLICATIONS

PLUS:

★ SPACEWATCH

★ INDUSTRY NEWS

★ LOGIC PUZZLE

★ MARKET PLACE

★ PROJECTS GUIIDE

★ PRINTING PE

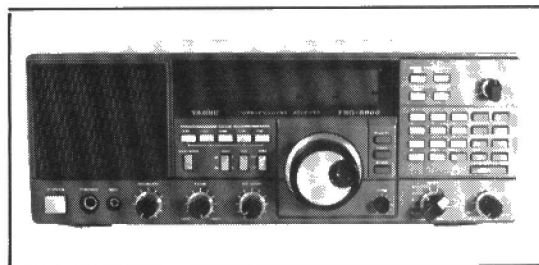THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

PRACTICAL ELECTRONICS

CONSTRUCTIONAL PROJECTS

SPECIAL FEATURES

REGULAR FEATURES

NEXT MONTH . . .

There's more to interest you in the JULY issue –

**WORD GENERATOR ● ANALOGUE TECHNIQUES ● FLIGHT 68K
REVIEW ● AUTO BUTLER ● EVENT COUNTER ● BBC INTERUPTS ●
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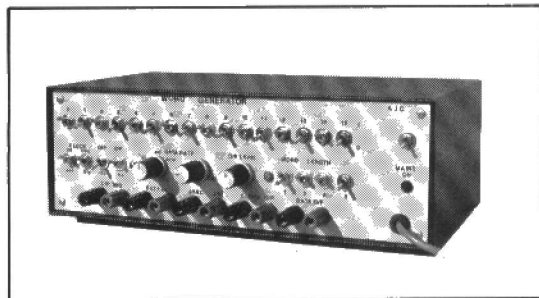
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS

CATALOGUE CASEBOOK

Last month we received details of the following catalogues and literature:

Cricklewood Electronics. Catalogue of electronic components and accessories **vital to the home constructor.** The cat's whisker cat – see their cover photo! **Cricklewood Electronics Ltd.,** 40 Cricklewood Broadway, London NW2 3ET. 01-450 0995.

Electromail. Over 700 pages of 'easy-to-buy' electronic and electrical products in their **March–June 1987 Catalogue.** A huge source of quality products. **Electromail,** PO Box 33, Corby, Northants NN17 9EL. 0536-204555.

Ericsson. New brochure **illustrating connector ranges** for micro, mini and mainframe users. **Ericsson Information Systems Ltd.,** 72 Northolt Road, Harrow, Middlesex HA2 0HE. 01-422 3442.

Gould Electronics. Publication announcement of new short form colour illustrated **catalogue of oscilloscopes** and allied systems. **Gould Electronics Ltd.,** Roebuck Road, Hainault, Ilford, Essex IG6 3UE. 01-500 1000.

Hitachi. Two free application design guides, 110 and 50 pages respectively, for systems designers using multiport video RAMs and Pseudo-Static RAMs. **Hitachi Electronic Components (UK) Ltd.,** 21 Upton Road, Watford, Herts WD1 7TP. 0923-46488.

Rapid Terminals. The 'Extra' colour illustrated **magazine and catalogue of computers** and associated products. **Rapid Terminals,** Rapid House, Denmark Street, High Wycombe, Bucks HP11 2BR. 0494-450111.

Siemens Components. Much more a magazine than a catalogue. Very informative with well written and **illustrated articles and essays. Siemens Ltd.,** Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. 0932-785691.

Thermaloy Inc. Comprehensive 94 page **catalogue of heat sinks,** insulating and semiconductor accessories. A wealth of data. **MCP Electronics Ltd.,** Alperton, Wembley, Middlesex. 01-902 1191.

WHAT'S NEW
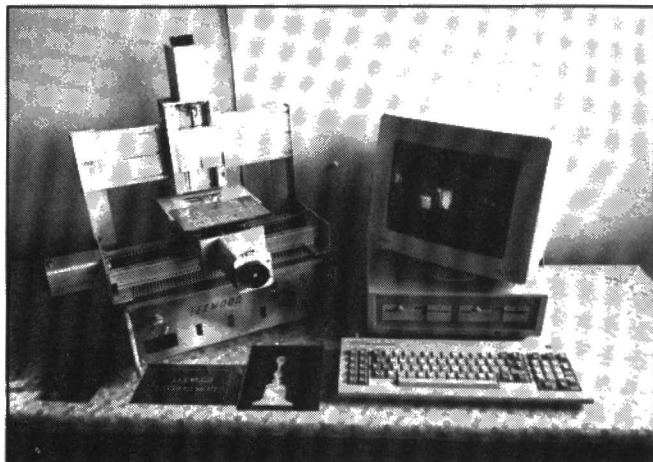
Easy as XYZ

Leewood Developments' range of three-axis positioning tables now has the benefit of an improved control interface which can be directly linked to a number of CAD packages coming into use. The interface commands are very similar to plotter commands, so that many CAD plotter/driver outputs can be adapted to drive the machine directly. Communication with the controller is via RS232, which allows most computers to be used as a host machine to send the ASCII command strings.

Linear Interpolation is standard on the X and Y axis which, combined with arc/circle vectors generated from the host computer's software, enables accurate cutting of curves to a resolution of down to one motor step. Applications so far include p.c.b. drilling, engraving and milling/drilling of light metal components.

The controller is available separately for users who want to connect their own stepper motor driven machines.

Contact: **Leewood Developments Ltd., Leewood Works, Upton, Hungtindon, Cambs PE17 5YQ. Tel. 0480 890860.**

Cirkit gets award

Cirkit Distribution are now supplying, as sole UK distributors, two ranges of surface mounting components from two manufacturers with whom they have long been associated.

Alps Electric Co. have introduced fixed chip resistors in power ratings from 0.1W to 1W with three-layer, erosion free electrodes, and multilayer ceramic chip capacitors of two types, 50V Class 1 in ranges in the 0.5pf to 4700pf band, and 25V or 50V Class 2 in ranges in the 220pf to 0.33uf band. These can be combined to provide R/C networks for automatic insertion on surface mount p.c.b.s.

Toko Inc. are introducing large chip inductors for reflow or dip soldering. These include a low profile adjustable version with a range of 30 to 300MHz, inductance from 0.01 to $1.2\mu H$, and bias oscillator type coils in the 10 to 100kHz bandwidth, inductances from $50\mu H$ to 7.5MH. Toko are also bringing in surface mounted communications and video filters, and TTL compatible delay lines with buffered inputs and outputs, giving delay times from 20ns to 30ns. Toko, through Cirkit, will supply components to customers own requirements.

These are featured in Cirkit's industrial catalogue, run by Cirkit Distribution. Cirkit Holdings supplies the well known catalogue for non-industrial customers.

Cirkit's electronic construction kits are being used at the Dhahran Technical Training Institute in the Middle East as part of their two year practical training course. The kits cover subjects from robotics to transmission lines. Cirkit established an educational division in 1986 to supply schools and colleges in the UK and overseas, and as part of a corporate emphasis on supporting practical education in electronics, instituted the Young Electronics Designer Award Scheme (YEDA).
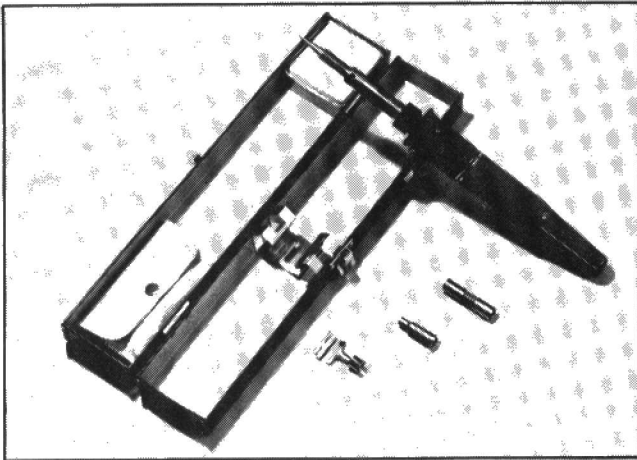
Enquiries to either Cirkit Distribution or Cirkit Holdings can be addressed, as appropriate, to **Park Lane, Broxbourne, Herts EN10 7NQ. Tel. in either case (0992) 444111.**

Hot point

Master Heat Tools are the suppliers of the Ultratorch 3 flameless heat tool, soldering iron and butane torch in one compact unit. Ultratorch 3 generates temperatures of over 1260 degrees C as a butane torch, up to 700 degrees C as a heat tool and up to 500 degrees C as a soldering iron. The complete kit comes with a solder tip, heat tool tip, heat shrink attachment, torch attachment and metal carrying case. The unit runs on butane lighter fuel, making it easily portable and inexpensive to run. Various extra trips are also available.

Contact: **Master Heat Tools, Unit M, Portway Industrial Estate, Andover, Hants SP10 3LU. Tel. 0264 51347.**

Fane would build

Fane Acoustics, makers of some of the UK's most highly regarded loudspeakers, have after three years and 50,000 copies been forced by rising prices to raise the price of their acclaimed handbook Loudspeaker Enclosure Design and Construction. The price is now £3.50, and the handbook can be ordered from **Fane Acoustics Ltd., 286 Bradford Road, Batley, W. Yorks WF17 5PW. Tel. 0924 476431.**
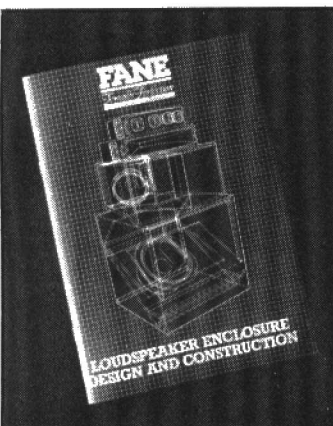
Sinclair scores again

Sir Clive Sinclair is back in the personal computer arena again – with a Z80-based, all-black, chocolate-box sized machine with a memory reliant on special cartridges and a limited number of output ports.

Despite a few Sinclair style trademarks, the new Z88 is different enough to make people sit up and take notice. Judging by its specification, it is a small and serious machine, offering, at a home micro price, the benefits of portability, on-board business style software, and up to 3 Mbytes of memory via eprom expansion cartridges.

The computer was launched at the Birmingham 'Which Computer' show at the National ·Exhibition Centre, 17–20 February. Over the counter sales are not planned until the second half of 1987, but the Z88 will probably be a familiar sight in the press. The machine itself is 11½in by 8¼in by ⅞in (293 by 209 by 23mm), weighs less than two pounds and is powered by four AA sized batteries, giving around 20 hours of computing or a year of standby, with full battery backup for the RAM. The built in screen incorporates a dark blue on grey l.c.d. 8 line by 80 column display dubbed 'supertwist' and there are three cartridge ports for memory expansion, and an RS232 serial printer port.

What about memory? The machine has a basic RAM of 32K, with 15K user RAM, but this is expandable via the three cartridge ports and 32K, 128K and 1M solid state RAM cartridges up to 3 Mbytes of memory. Alternatively, the ports can be occupied by a similar configuration of removeable eprom cartridges. Cartridges are more compact and more resilient than disc or tape storage, and provide very fast access to their contents.

The screen area is divided into four windows: the working area, the menu options, machine status report, including battery status, and a new feature, a screen map showing the complete layout of the current page, which is updated as work proceeds.

Built-in software, which is intended to make the Z88 entirely self contained, includes a spreadsheet, database selection, word processing, diary, calendar, real time clock and alarm. The computer's operating system, which is Cambridge Computers' own specially developed 'C-DOS' allows the user to switch tasks instantaneously, for example, between word processing and the diary, without extra saving and reloading. An almost unlimited number of separate tasks can be open at the same time – a great time saver. The operating system supports data exchange facilities to the IBM PC and compatibles.

The programming language and assembler used is the widely known BBC Basic, and there is a Z80 expansion bus for future expansion options.

The computer itself is being sold by mail order from Cambridge at an introductory price of £229.95 (£199.95 ex VAT), plus £7.50 post and packing. **Cambridge Computers Ltd., FREEPOST, Cambridge CB4 1BR. Tel. 0223 312216.**

Super cheap signals

Flight Electronics are opening up a 'vast new range' of test and measurement equipment by agreement with manufacturers GW Instrumentation of Taiwan. The equipment is expected to be around 20 per cent cheaper than branded units from other sources. Flight will be marketing the equipment directly in the UK and Eire.

The range includes oscilloscopes, function generators, multimeters, power supplies, other types of meter, frequency counter, audio/r.f. generators and accessories. Twenty six different bench power supplies from 18W to 200W cater for most applications in electronics and education. Seven oscilloscope types give capabilities up to 40MHz dual beam delayed sweep, and seven function generators offer facilities from very basic to a double function model with a 0.1Hz to 14MHz range.

GW Instrumentation exports mainly to the USA and Japan. A full description of the range is included in Flight's catalogue now available from **Suzanne Kittow, Flight Electronics, Ascupart Street, Southampton SO1 1LU. Tel. 0703 227721.**

NEWS AND MARKET PLACE

CHIP COUNT!

This month's list of new component details received.

82385 – 32 bit cache memory controller (IT).
80386 – 32 bit high speed CPU, coprocessor (IT).
80387 – high performance 32 bit numerics coprocessor (IT).
CHAS 68000 – 16 bit microprocessor trainer (LJ).
CARL 68000 – 16 bit microprocessor trainer (LJ).
IMS M212 – disc processor transputer periferal (RP).
Long-Life Hyper-Red LEDs announcement (ML).
PC 2000 – Programmable Controller Trainer (LJ).
TP1900 – 175MHz video display driver IC (MC).
TPV657. 860MHz Class A, 6 watt wide band transistor (MP).
MAX232 – dual RS232 interface for 5V operation (VS).

Mitsubishi announce development of two very high speed one megabit EPROMs, and development of a 4-megabit DRAM. (They only quote a Japan telephone no – Tokyo 218 2171).

Manufacturers, and contact telephone numbers for further details. (HT) Hitachi, 0923-46488. (IT) Intel, 0793-696204. (LJ) LJ Electronics, 0603-748001. (MC) MCP Electronics, 01-902-6146. (ML) Mullard, 01-580-6633. (RP) Rapid Silicon, 0494-442266. (VS) Vero Speed, 0703 644555.

Watford Gap Closed

WE are delighted to learn that despite earlier understandings to the contrary, Watford Electronics have no intention of retiring from the sale of electronic components (PE Mar 87). Many hobbyists will breath a sigh of relief at this affirmation of a continuing commitment to supplying full ranges of individual components.

For over a decade, Watford have been a major source of supply for many constructors, though of recent years they have also diversified to additional ranges, such as computer – related equipment. Their retreat from the sale of essential basic parts would have created a significant gap within the list of major suppliers catering for the redeveloping hobbyist electroncis boom.

Watford Electronics are at 250 High Street, Watford, Herts, WD1 2AN. Tel: 0923-37774.

Pocket Pyrometer

THE Oryx pocket sized Pyrometer ODP1, for specific use with soldering irons, ensures against poor quality soldering. Users can be certain that tip temperatures are at a safe level for the product being soldered.

A non-flamable insulated lead feeds a thermocouple probe, which is detachable. By placing the iron tip in the thermocouple loop, temperatures between 200°C to 450°C will be displayed.

Weight is only 300gms and it is 5½ x 3" in size, using a 9 Volt battery to give 200 hours of life. Simple and effective, with obvious cost savings. The unit incorporates a low battery indicator.

Contact: Oryx, Greenwood Electronics, 28 Portman Road, READING RG3 1NE, Tel: 0734 595843

Vari-Speed Turntable

B.K. Electronics have introduced a variable speed turntable chassis to complement their growing range of audio equipment, and claim an unsurpassable price/ performance standard. The prime objective of this turntable is to fulfill the requirement for a realistically priced product. The electro-mechanical design features incorporated into the turntable, B.K. Electronics say, satisfy the exacting demands for quality sound from the disco, leisure and studio environments. The Vari-Speed can also be applied to domestic hi-fidelity systems.

The many features include: electronic speed control, 33⅓ and 45 rpm with separate variable pitch control; high torque DC motor with electronic servo drive; quick start; rigid steel chassis; full size 12" machined die-cast platter with strobed rim; belt driven; five point suspension; optically illuminated neon strobe prism; heavy duty transit screws; precision balanced 'S' shaped tone arm; universal head shell with standard ½" cartridge fixings; precision callibrated counter balance; anti-skate device; viscose damped cue lever; complete with integral mains power supply; power requirement 220–240V, 50–60Hz. Size: 390mm x 305mm. Weight: 3.25Kg. Supplied complete with paper mounting cut out template. Price: £49.99 + £3.00 P&P, including VAT.

Contact: B.K. Electronics, Unit 5, Comet Way, Southend-on-Sea, Essex SS2 6TR. Tel: (0702) 527572.
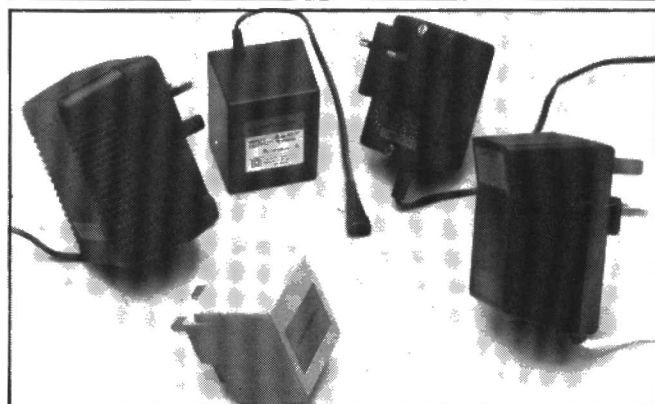
Mini Mains Adaptors

Clairtronic announce a new range of low voltage AC & DC Power Adaptors for use in a wide range of electronic, industrial and commercial applications for wall socket plug-in power units.

The range comprises AC only versions up to 500 mA, DC un-regulated to 500 mA and DC regulated to 1 Amp. Output voltages range from 5V to 12V fixed, with universal variable units offering a choice of five or six standard DC levels.

All adaptors employ the latest safety features including internal thermal fuse and sleeved live pins.

A new feature of the range is the optional output connector which may be selected from one of five terminations generally used with mains adaptors. The choice includes two jack plugs, two co-axial plugs and the well known 4-way spider. Any one of these connector assemblies may be plugged in to the 15 mm cable integral to each Adaptor.
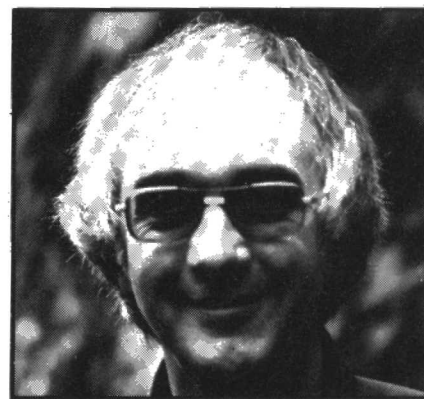
Contact: Clairtronic Ltd., Churchfield Road, Chalfont St Peter, Bucks SL9 9EP. Tel: (0753) 887227.
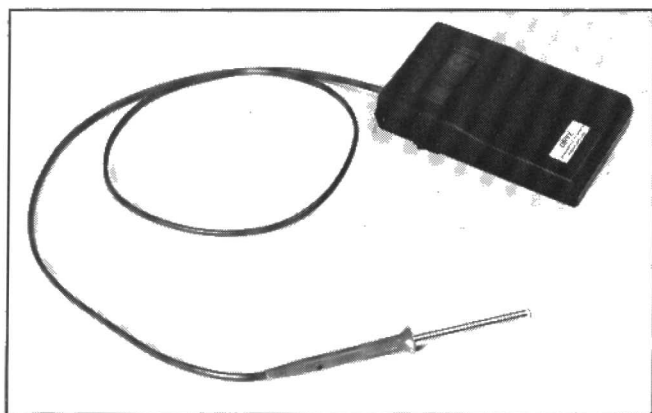
THE LEADING EDGE
NO MORE 'FREE' TV

Investors in expensive satellite TV receivers face more expense, or a glum time, when debs starts sending scrambled signals.

BY BARRY FOX

I don't like to be the bringer of bad tidings, and say I told you so, but anyone who has paid up to £2,000 for a backyard satellite dish system is soon in for a nasty shock.

By the end of this year the premium broadcast signals which they have been receiving will almost certainly be scrambled. Dish owners will then have to pay several hundred pounds for the extra electronics needed to de-scramble the signals plus an annual copyright licence fee which is stiffer than the BBC licence -- or make do with watching programmes which are supported by heavy advertising.

For many months now, the firms broadcasting premium programmes by satellite for cable stations have been talking about scrambling their signals to prevent home dish owners watching their programmes free. Some, but by no means all, of the firms which sell satellite dish systems for home reception have been saving their skins by publishing small print warnings about this. But the print is usually very small. And most of the firms selling home dishes have just swept the issue under the carpet and issued no warnings at all.

I spoke recently with Andy Birchall, Chief Executive of the Premiere movie channel. "We have to scramble", says Birchall, "to protect the interests of the film companies who supply us".

Premiere buys rights on a feature film, and beams it up to the Intelsat satellite for cable stations to receive and distribute to their subscribers. Fees are fed back from the subscribers, to the cable station, to Premiere, and thus to the film company. Obviously, if people are watching at home on a domestic dish, they are getting something for nothing.

A year or so ago an agency service, called Galaxy, tried to collect copyright fees on a voluntary basis from home dish owners. The plan failed. Now anyone owning a dish has to volunteer the money, £75 a year, to Premiere. Only 200 people in Britain pay up. Out of how many? No-one knows.

The Department of Trade and Industry, which sells £10 satellite dish licences, has around 2000 dish owners on record. Clearly there are more dishes than that, plus several thousand on the Continent owned by English speaking expatriates. "We will know exactly how many there are by the number of phone calls we get the morning after we start scrambling", says Birchall.

The DTI licence form clearly warns would-be viewers that they must "obtain all relevant consents and authorisations", relating to copyright. So there will be no sympathy from the government for dish owners who find their programmes have disappeared overnight.

Decoders will initially be in short supply. Cable stations will get them first. Then honest, voluntary fee-payers. The several thousand dishonest viewers will be offered amnesty and the chance to buy a decoder when stocks are available.

Decoder price will depend on the scrambling technology used. Premiere has been agonizing over the choice between two options. The first is what Birchall describes as "cheap and nasty". It is a modification of the conventional PAL tv signal. The synchronization pulses are doctored so that the pictures break up on screen unless a decoder is used. The snag is that the system can be easily defeated by an electronics engineer. Premiere know that soon after scrambling starts there will be a grey market in unauthorised decoders.

The more elegant solution is to use the completely new MAC tv standard developed by the IBA and adopted throughout Europe for future direct broadcasting from satellite. The MAC signal needs a MAC decoder for normal reception and the MAC signal can be additionally encrypted so that it can only be received by a MAC decoder with extra de-encryption circuitry. Inevitably all this costs much more than simple PAL signal doctoring. The raw price of the MAC decoder chips will be at least £30. And they are not yet available. A decoder with de-encryption circuit will cost several hundred pounds.

Premiere may start using a PAL scrambler and then switch to MAC. So the dish owner will first need to buy one de-scrambling system, then another, in addition to paying the annual copyright fee. For cable stations, the hardware costs will be insignificant. But for someone with a home dish they will be prohibitive.

One satellite service is already scrambled. Rupert Murdoch's Sky Channel is aimed at cable stations and reaches over 8 million homes in 18 countries across Europe. Sky has no interest in reaching a few thousand more by direct reception via backyard dishes. But Sky's rival, Super Channel, does not scramble and has no intention of doing so. "The more the merrier", say joint managing directors Richard Hooper (ex BT's Prestel viewdata) and Charles Levision (ex WEA Records). Super Channel is funded by all the ITV companies, except TV-AM and Thames. TV-AM was struggling to survive when, in January 1986, the ITV companies had to decide whether or not to buy shares in Super Channel. Thames decided to buy shares in the Luxembourg private company Astra, which hopes to launch its own satellite this year or next.

Although there are 60 cable stations in Britain theoretically capable of receiving Super Channel (or Sky) on satellite dishes for distribution to their subscribers, and although their cables 'pass' one million homes, less than 0.2 million of these homes have paid for connection to a cable service. Only around half these, i.e. 100,000, are served by a cable station which has equipped itself to handle the new Super Channel. By comparison over 2.5 million households in the Netherlands and 1.5 million in West Germany are able to receive Super Channel. In the Netherlands, over 3 million homes can now get Sky by cable.

Super Channel – like Sky – has no illusions about the so-called 'boom' in home satellite dish systems. "There are probably only around 10,000 home dishes throughout the whole of Europe", says Richard Hooper. "The direct satellite reception market is still peanuts. And we don't expect it to become significant before 1995."

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All editorial correspondence should be addressed to the editor and any letters requiring a reply should be accompanied by a stamped addressed envelope. Please address editorial correspondence to: Practical Electronics, 16 Garway Rd., London W2 4NH. Tel. 01-221 5422
We regret that lengthy technical enquiries cannot be answered over the phone.

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PE EDITORIAL TEL. 01-221 5422
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WRITING FOR PE

READERS frequently ask how they can write for PE, and what I look for when assessing the suitability of articles. In simple terms, I am looking for texts and circuits that are good examples of current or emerging technology; potentially useful or interesting to a wide readership; educationally informative; displaying a significantly different approach to a common subject; of a nature not previously published; explanations of a topical subject; showing practical computer control functions; illustrating the relationship of electronics to other disciplines or technologies, e.g. in industry, medicine, food production, conservation, energy harnessing, space, communications, information storage, entertainment, consumer applications, and so on.

Submitted texts should be typewritten or computer printed, (using a new ribbon!), with double line spacing, good margins, and in upper and lower case. Length depends on the subject, but as as guide, a full column of PE holds about 500 words, or two typed A4 pages.

Throughout an article, you should pay close attention to its logical progression, to spelling, and to grammar. Your approach should be positive, interesting and informative, avoiding repetition and long complex sentences, though don't be too terse. Try to communicate enthusiasmm, but whilst a light hearted attitude may assist some articles, be wary of too much humour. Insert sub-headings where applicable, and include a good variety of relevant drawings (and photographs if possible).

For constructional articles, the opening paragraph should preferably be a brief statement of the objectives of the project. Next should come any relevant technical or general interest background information, followed by a detailed description of the circuitry, construction, testing and use.

Drawings should be neat and conform to our normal style for component representations, with part numbers and values entered clearly. If you are fortunate enough to have a CAD system, please use it! Working prototypes should be sent, and preferably with control legends already neatly lettered. We also need the original PCB track master (either lifesize or twice lifesize), a component positioning chart, circuit and wiring diagrams, a basic-function block diagram, and a full parts list arranged in our conventional order and style. Look at back issues of PE for such examples; total conformity is not vital, but consistency can make the Editor's job easier! However, it is pertinent to mention that some styles are under review, since abbreviations, like l.e.d., EPROM, BASIC, etc., have become absorbed into the language as words in their own right.

If you have a worthwhile project or article to offer, please send it to me – I shall be delighted to give it careful consideration, and hopefully publish it for the benefit of all readers.

THE EDITOR

SYNTHESISED AF GENERATOR

THE AF SIG-GEN GOES DIGITAL

BY THE PROF

Frequency synthesised audio signals have a major advantage: switch-controlled, crystal derived signals are extremely accurate, and do not present the calibration problems associated with analogue sig-gens.

I do not know how many audio frequency signal generator designs have been published in the past, but there have certainly been a great many of them. I do not know what percentage of these have been based on the standard Wien bridge oscillator with thermistor stablisation, but I would expect the percentage to be very high. The traditional Wien bridge oscillator designs certainly provide a very high level of performance, with distortion levels usually well under 1%, and in some cases at around 0.1% or less. This is more than adequate for frequency response and general testing (such as voltage gain measurements), and the better designs are suitable for distortion testing on high quality audio equipment.

There is actually another common form of audio signal generator these days, in the form of function generators which are often based on a version of the 8038 integrated circuit. These have a triangular oscillator which is fed to a trigger circuit to provide a squarewave signal, and to a non-linear amplifier which rounds off the peaks of the waveforms to give a reasonably accurate sinewave. By reasonably accurate I mean a signal with what is usually about 1% to 4% of total harmonic distortion. This is not particularly impressive, but is still perfectly satisfactory for frequency response measurements and many other forms of audio testing.

This audio signal generator design uses a different approach, and one which I have not encountered before (although I would not be so foolhardy as to claim it was a new way of tackling the problem). It is based on frequency synthesiser techniques, plus an interesting oscillator which could be described as an l.c.o. (logic controlled oscillator). It converts the logic pulses from the frequency synthesiser circuit into a reasonable sinewave signal at either a fiftieth or a hundredth of the input frequency. The output signal is a digital sinewave which, if carefully examined using an oscilloscope, shows the characteristic stepped nature of a digitized signal. This limits the quality of the signal, but the distortion level is comparable to that of a simple function generator type sinewave source, and it is perfectly adequate for most types of audio testing.

The digital approach to audio signal generation might seem like an interesting but impractical way of doing things, but there is one very real advantage to this method which makes it very worthwhile, particularly for a home constructor design. Producing a conventional Wien or function generator type audio signal generator is not difficult, but fitting the frequency control with an accurate dial quite definitely is. Apart from the difficulty in producing a neat and accurate dial, some means of determining the correct calibration points is needed. Without access to a suitable frequency meter this can be difficult or even impossible. It is not necessary to be able to set the output frequency with a high degree of precision for all types of testing, but one of the most common tests is frequency response checking. This obviously requires the dial to be accurately calibrated over the full audio frequency range if meaningful results are to be obtained.

With the frequency synthesiser approach the output frequency is controlled by switches, and excellent accuracy is assured as all the frequencies are derived from a crystal oscillator. In fact the output frequencies should be accurate to within a small fraction of one percent. With this design two 10-way rotary switches are used to select frequencies from 100Hz to 10kHz in 100Hz increments. This gives coverage of considerably less than the full audio frequency range, but this is rectified by the inclusion of two additional switches. One of these can be set to double the output frequency, so that the coverage is from 200Hz to 20kHz in 200Hz steps, and the 20kHz upper limit of the audio range is encompassed. The other switch can be used to divide the output frequency by ten, so that the coverage is from 10Hz to 1kHz in 10Hz increments (or 20Hz to 2kHz in 20Hz steps if the x2 switch is used as well). With a frequency synthesiser it is not possible to obtain *any* desired output frequency, but the range of frequencies available in this case should be more than adequate for normal frequency response measuring purposes, including such things as testing high Q bandpass and notch filters. The accuracy with which the output frequency can be set is actually likely to be better than that which can be achieved with many conventional designs where the dial accuracy and resolution are quite limited.

The output from the unit is about 6 volts peak to peak, and is virtually constant over the full frequency range.
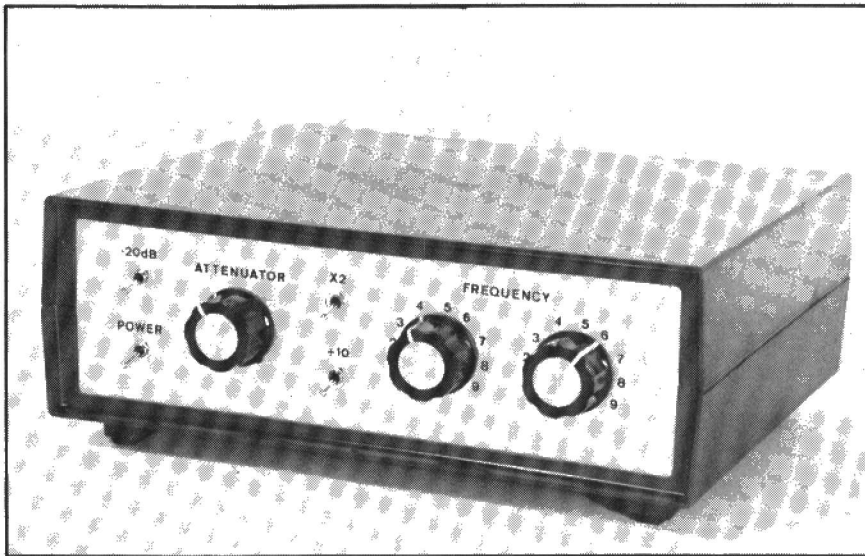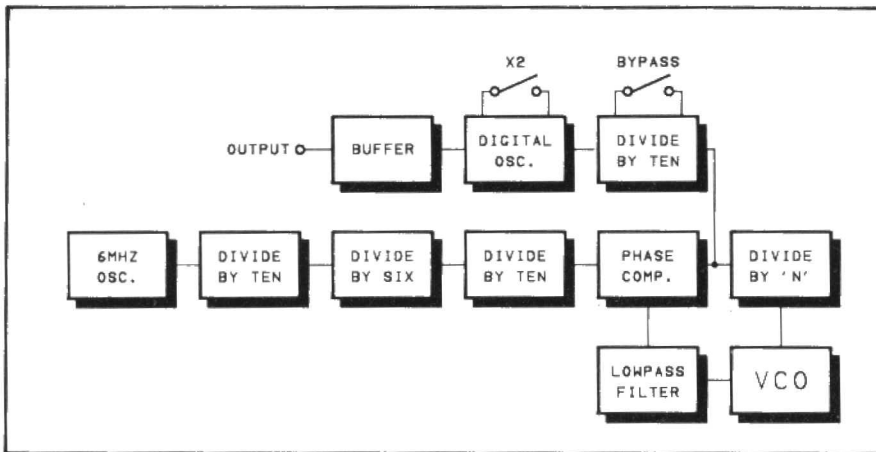
Fig.1. *The Digital AF Generator Block diagram*

There is a 20dB attenuation switch plus a continuously variable output attenuator. The use of low power CMOS circuitry enables the unit to be powered from an internal 9 volt battery.

SYSTEM OPERATION

The block diagram for the Synthesised Audio Generator appears in Fig.1. the subject of frequency synthesis is covered in some detail in an accompanying article in this month's issue, and so we will only consider the operation of this design fairly briefly. Those who require more information on the subject of frequency synthesis should refer to the other article.

Audio frequency synthesis can be rather difficult in that it is necessary to have a low reference frequency in order to give adequate resolution. With a reference frequency of perhaps only about 10 Hertz the phase locked loop would need to have a fairly slow response time in order to give reliable locking, and this could result in the unit taking several seconds or more in order to respond to changes in the selected frequency. In this case the problem is avoided completely by the use of an oscillator which requires a clock signal at fifty or one hundred times the required output frequency. This means that the frequency synthesiser part of the unit is working at relatively high frequencies, and consequently a high reference frequency and fast response time are used.

The reference frequency is derived from a 6MHz crystal oscillator via a three stage divider chain which has division rates of ten, six, and ten again. This gives a 10kHz reference frequency to the phase locked loop. The latter is comprised of the phase comparator, voltage controlled oscillator (v.c.o.) and lowpass filter. The divide by 'N' circuit between the v.c.o. and the phase comparator results in the v.c.o. being locked onto the reference frequency, or some multiple of it, depending on the division rate used. In this case the divide by 'N' circuit can be set for division rates in the range 1 to 100, giving a range of output frequencies from 10kHz to 1MHz. This is fed to a divide by ten circuit which can be bypassed, but which gives a modified output frequency range of 1kHz to 100kHz when it is switched into circuit.

The digital oscillator normally operates with an output frequency that is one hundredth of the clock frequency, and this gives an output frequency range of 100Hz to 10KHz in 100Hz increments, or 10Hz to 1kHz in 10Hz increments if the optional divide by ten circuit is switched in. This gives coverage of most of the audio frequency range, but leaves a gap from 10kHz to 20kHz. To overcome this, the digital oscillator can

be switched to the mode where its output frequency is at one fiftieth of the clock frequency. This doubles the output frequency, and extends the maximum available output frequency to upto the 20kHz upper limit of the audio range. The unit should only be operated in this mode when really necessary, since the quality of the output signal is lower in the 'x2' mode of the digital oscillator.

A buffer amplifier at the output of the unit provides a low output impedance, and the variable and switched attenuators are included here.

CIRCUIT OPERATION

The clock, divider, and phase locked loop circuits are shown in Fig.2. The clock oscillator is a simple single transistor type based on TR1, and its output directly drives IC4 which is a 4017BE one of ten decoder. In this case it operates as a straightforward divide by ten circuit with only the 'carry out' output being utilized. IC5 and IC6 are the divide by six and second divide by ten stages, and these are both 4018BE divide by 'N' devices wired in the appropriate modes.

IC7 is the phase locked loop, and this is a 4046BE low power CMOS type. Although it might seem as though practically any phase locked loop device will operate in this circuit with its relatively low maximum v.c.o. frequency, the requirements are more awkward than it might at first appear. CMOS compatibility and a low power consumption are a decided asset, but what makes the 4046BE suitable where most other types would fail is its ability to operate over a very wide v.c.o. frequency range. The v.c.o. must operate over a 100 to 1 frequency range, whereas most phase locked loop designs will only operate over a 10 to 1 range, or in some cases a range of less than 2 to 1. The 4046BE actually has two phase comparators; one where the free running v.c.o. goes to the centre frequency in the normal way, and one where it drops to zero frequency. It is this second phase comparator which is used in this circuit,
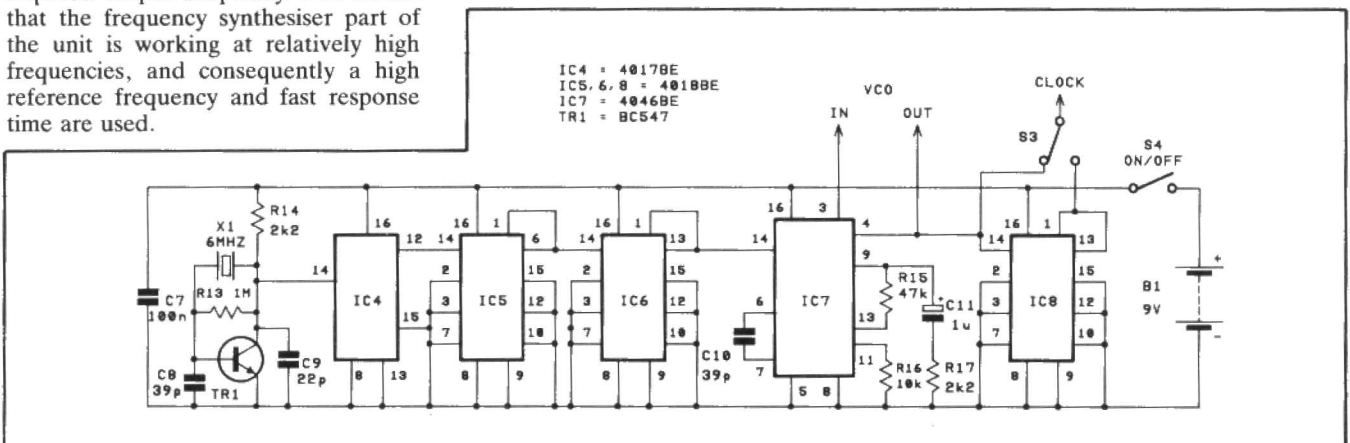

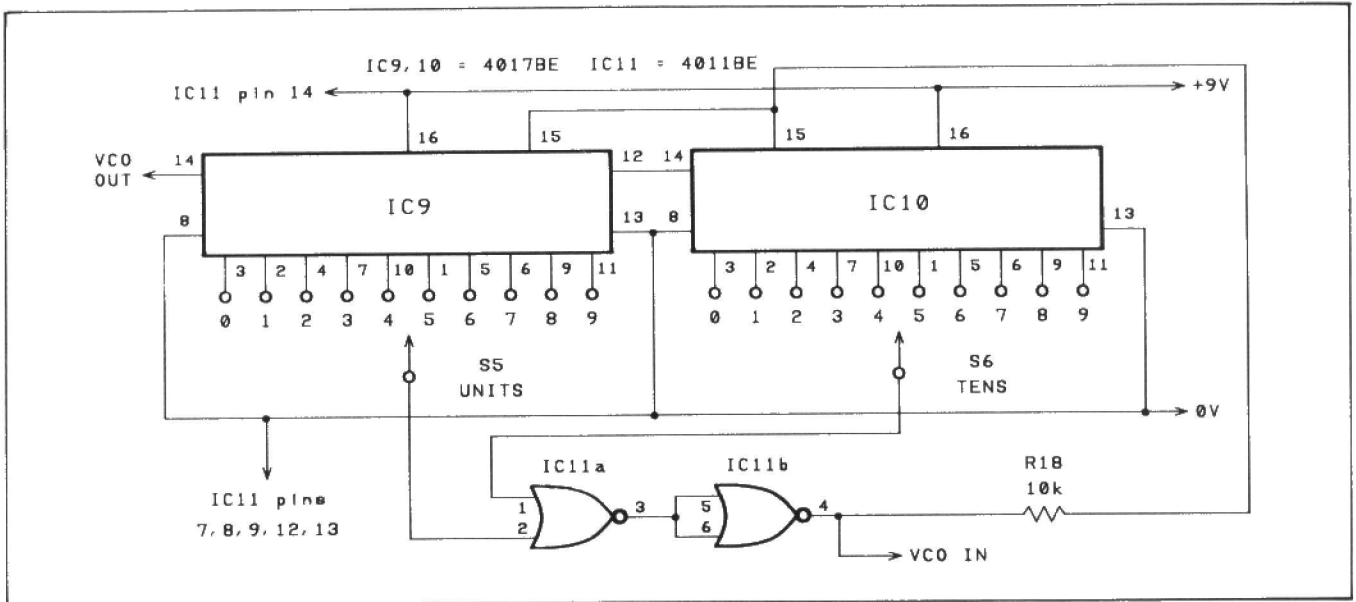**Fig.2.** *The clock, divider, and P.L.L. circuit*

Fig.3. *The divide by 'N' circuit diagram*

and it is largely this unusual mode of operation which enables such a wide tracking range to be achieved. The ability of the v.c.o. to be adjusted over an enormous operating range via the control voltage is another factor which contributes to the wide tracking range.

C10 and R16 are the timing components for the v.c.o., while R15 and C11 form the lowpass filter. The ultra-high input resistance at the v.c.o. input of IC7 helps to simplify design of the lowpass filter. R17 slightly reduces the efficiency of the filter, but it has the beneficial effect of reducing overshoot and gives a faster lock-on when the output frequency is changed.

IC8 is the divide by ten circuit driven from the v.c.o. output and this is another 4018BE. S34 is used to switch it in or out of circuit, as desired.

The divide by 'N' circuit appears in Fig.3, and this is built around two 4017BE one of ten decoders (IC9 and IC10). These are wired in series so as to give a divide by 100 action, but the 'carry out' output from the second stage (IC10) is ignored. Instead, two gates of IC11 are wired to give a simple 2 input AND

action, and these are used to reset IC9 and IC10 when the appropriate two outputs go high. For those who are unfamiliar with one of ten decoders it should perhaps be explained that they have ten outputs numbered from '0' to '9', and these each go high, in sequence, for one clock cycle. If, for example, S6 is set to '3' and S5 is set to '5', 35 input cycles will be needed before the counter is taken to the point where both these two outputs go high. When this happens the output of IC11b goes high and resets both devices back to zero. After a further 35 input cycles the '3' and '5' outputs go high again, the two counters are reset to zero once more, and so on, with a divide by 35 action being obtained. By setting S5 and S6 at the appropriate settings it is possible to obtain any division rate within the range of the circuit. The output signal is taken from the output of IC11b and is a series of narrow pulses. In fact the pulses might be too narrow for the phased locked loop to lock onto them properly, and in order to avoid this R18 is included between IC11b and the reset inputs. This has the effect of slightly delaying the reset action

so that the output pulses are lengthened somewhat, although they are still well under a microsecond in duration.

OSCILLATOR

Fig.4 shows the circuit diagram for the digital oscillator, buffer, and attenuator stages of the unit.

The oscillator is based on an MF10CN switched capacitor filter device (IC1). The MF10CN actually contains two second order filters, but in this circuit only one section of the device is used. A switched capacitor filter is similar to an ordinary C–R type, but the resistor is replaced with a low value capacitor and an electronic switch, as in Fig.5. Here Ca and the switch replace the resistor, while Cb is the normal filter capacitor.

With a normal C–R filter the resistor limits the rate at which current can charge and discharge the capacitor, and this gives the lowpass filtering. The effect is much the same with a switched capacitor type, but the rate of charge/discharge is limited by the ability of Ca to transfer current from the input to the output, or vice versa, depending on the
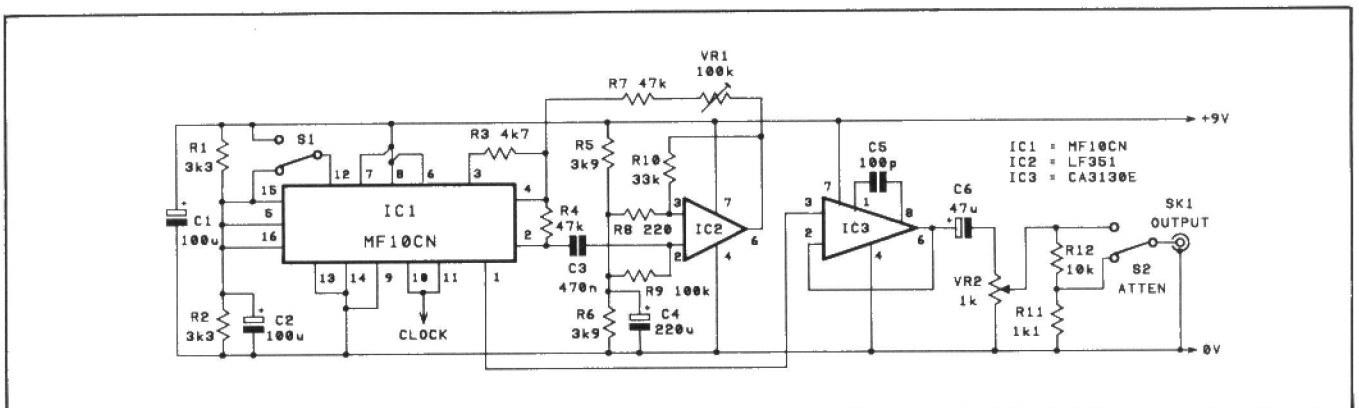

Fig.4. *The circuit of the digital oscillator and output stages*
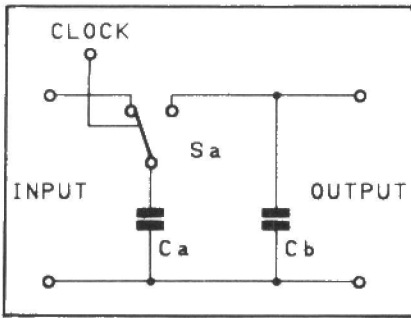
Fig.5. *The basic switched capacitor filter arrangement*

signal polarity. This transfer of current is achieved by using a clock oscillator to continuously switch Sa from one setting to the other. How rapidly or otherwise the transfer is to be achieved depends on the value of Ca and on the clock frequency. It is this second factor that is of importance, since it gives a cutoff frequency that is a subdivision of the clock frequency, and with the MF10CN the operating frequency of the filter can be nominally either one hundredth or one fiftieth of the clock frequency.

The circuit of Fig.4 operates by having the filter configured as a high Q bandpass type which is made to 'ring' continuously due to feedback provided by IC2. VR1 is adjusted for a feedback level which gives a strong but unclipped sinewave output. This configuration seems to give a consistent output level over the full frequency range covered, and there is no need for any stabilisation of the feedback level. S1 switches IC1 between the 50:1 and 100:1 modes, and these are obtained by taking pin 12 to the positive and mid supply rails respectively. This circuit only has a single supply rail, and so R1, R2, and C2 are used to generate a mid-supply level for biasing purposes.

It has to be pointed out that there is not a perfect 50:1 and 100:1 relationship between the clock and output frequencies, and the overall accuracy of the unit does not quite equal that of the frequency synthesiser section. The error could be as much as 1.5%, but is typically only 0.2%. In either case the unit gives more precise output frequencies than most conventional signal generators, and is certainly accurate enough for even quite demanding frequency response measurements. As explained previously, the output signal is a digitized sinewave. This is an inevitable consequence of the switching mode of operation, with the charges from the switched capacitor causing the output signal to alter in rapid jumps rather than varying continuously. However, the steps in the output waveform are quite small and the distortion level is sufficiently low. Incidentally, a reasonable squarewave signal is generated at the output of IC2, and a second sinewave signal (90 degrees phase shifted from the original) is generated at pin 2 of IC1.

IC3 is the buffer amplifier and it is a simple operational amplifier voltage follower circuit. VR2 is the variable attenuator while R11, R12, and S2 provide the switched 20dB of attenuation. If 40dB of attenuation would be preferred then R11 should be reduced to 100 ohms in value.

Power is provided by a 9 volt battery, and the total current consumption of the unit is approximately 25 milliamps. A fairly high capacity battery such as a PP9 or six HP7 size cells in a plastic holder is therefore needed in order to power the unit economically.

CONSTRUCTION

With the exceptions of the controls, battery, and output socket, all the components fit onto a single printed circuit board, together with a substantial number of link wires. Details of the printed circuit board are provided in Fig.6.

There is nothing particularly unusual about construction of the board, but bear in mind that the integrated circuits are all MOS types apart from IC2, and that the appropriate handling precautions should therefore be taken
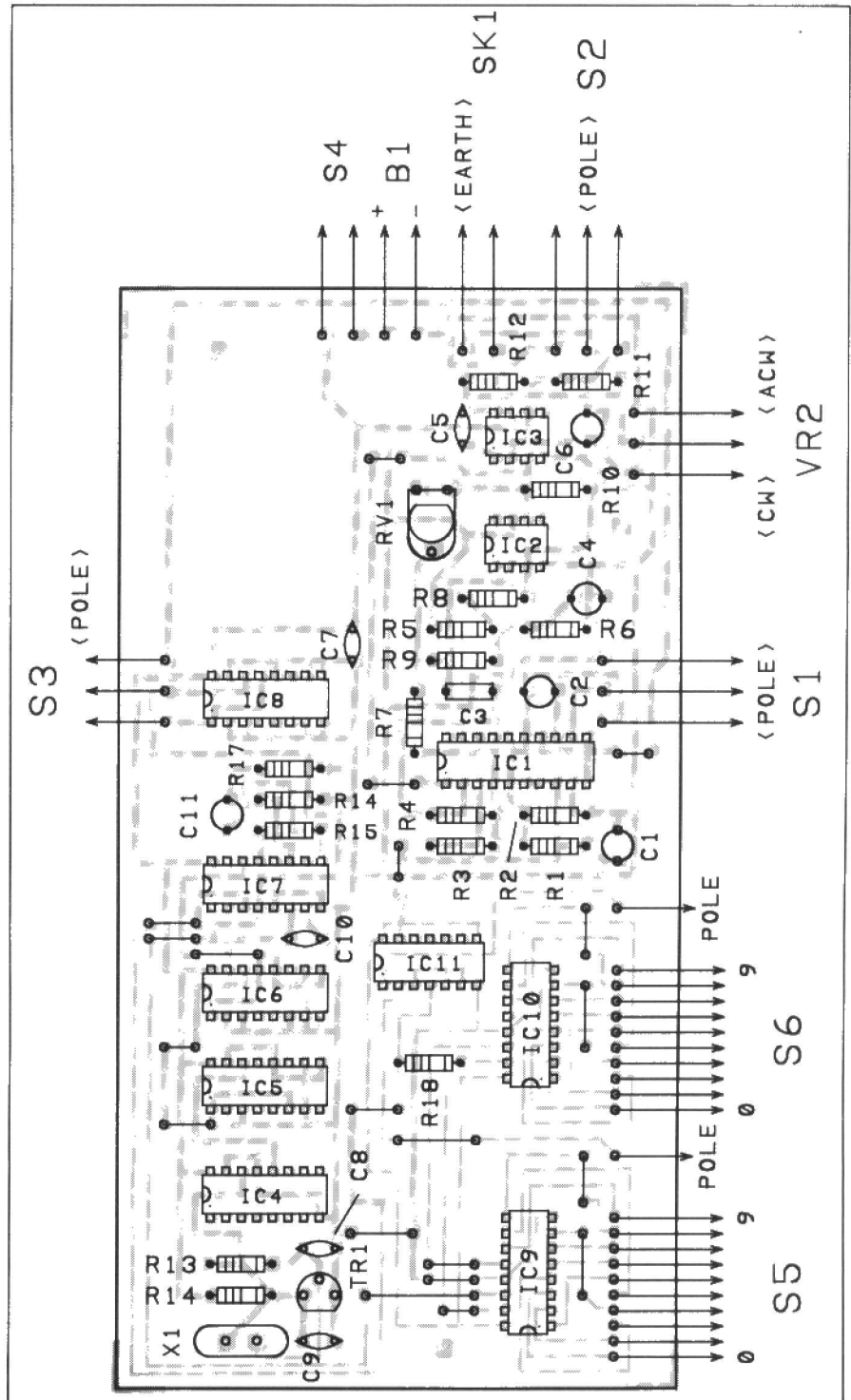
Fig.6. *Details of the printed circuit board*

SYNTHESISED AF GENERATOR

COMPONENTS . . .

RESISTORS

R1,R2	3k3 (2 off)
R3	4k7
R4,R7,R15	47k (3 off)
R5,R6	3k9 (2 off)
R8	220
R9	100k
R10	33k
R11	1k1 1%
R12	10k 1%
R13	1M
R14,R17	2k2 (2 off)
R16,R18	10k (2 off)

All 1/4 watt 5% unless noted)

CAPACITORS

C1,C2	100μ 10V radial elect (2 off)
C3	470n miniature polyester
C4	220μ 10V radial elect
C5	100p ceramic plate
C6	47μ 10V radial elect
C7	100n ceramic
C8,C10	39p ceramic plate (2 off)
C9	22p ceramic plate
C11	1μ 63V radial elect

SEMICONDUCTORS

IC1	MF10CN
IC2	LF351
IC3	CA3130E
IC4,IC9,IC10	4017BE (3 off)
IC5, IC6, IC8	4018BE (3 off)
IC7	4046BE
IC11	4011BE
TR1	BC547

POTENTIOMETERS

VR1	100k min hor preset
VR2	1k 1in

MISCELLANEOUS

SK1	3.5mm jack socket
S1,S2,S3	Miniature SPDT toggle (3 off)
S4	Miniature SPST toggle
S5,S6	12 way 1 pole rotary with end stop (2 off)
X1	Miniature wire ended 6MHZ crystal
B1	9 volt (e.g. PP9)

Instrument case about 231 x 181 x 77mm, printed circuit board, battery connector, 8 pin DIL IC holder (2 off), 14 pin DIL IC holder, 16 pin DIL IC holder (7 off), 20 pin DIL IC holder, control knob (3 off), wire, solder, etc.

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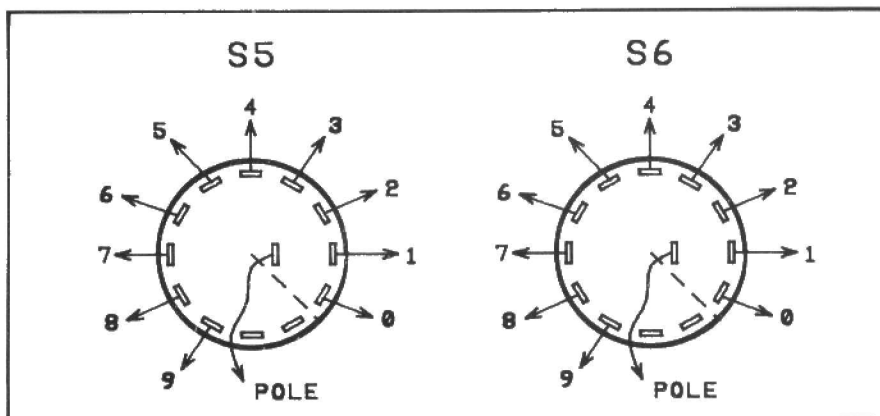
Fig.7. *Wiring to S5 and S6*

when dealing with these devices. At this stage only pins are fitted to the board at the points where connections to off-board components will be made.

An instrument case with outside dimensions of around 231 by 181 by 77 millimetres will comfortably accommodate the printed circuit board and other components. The precise front panel layout of the unit is not too important, but to make frequency setting easy it is advisable to mount S5 and S6 side by side, with S5 to the right of S6. On the prototype SK1 is a 3.5 millimetre jack socket mounted on the rear panel, but obviously any other type of two way audio connector can be used for SK1 if preferred, and there should be no difficulty in finding space for it on the front panel if necessary.

The printed circuit board is mounted on the base panel of the case, well towards the left hand side so as to leave room for the battery at the other end of the case. It is then wired up to the off-board components, and most of this wiring is quite straightforward. It is very easy to slip up with the rotary switches though, and Fig.7 should make it easier to get things right first time.

ADJUSTMENT

Before switching the unit on, set the attenuator controls for a reasonably high output signal level, and connect the output to an oscilloscope with the controls adjusted to realistic settings for the output signal that the generator should produce. Set VR1 at about half maximum resistance. Once switched on the unit should almost immediately burst into life and produce an output signal. If it does not, switch off and recheck all the wiring. If all is well, VR1 is adjusted for the lowest resistance setting (anti-clockwise adjustment gives reduced resistance) that gives an unclipped output signal at any setting of the frequency controls. Trying out the latter at various settings should soon reveal whether or not the frequency synthesiser is functioning properly. The unit should respond almost instantaneously to changes in the frequency controls. Although a setting of 10kHz might seem to be impossible, setting both S5 and S6 at '0' seems to give an output at this frequency rather than blocking operation of the unit, as one might have expected.
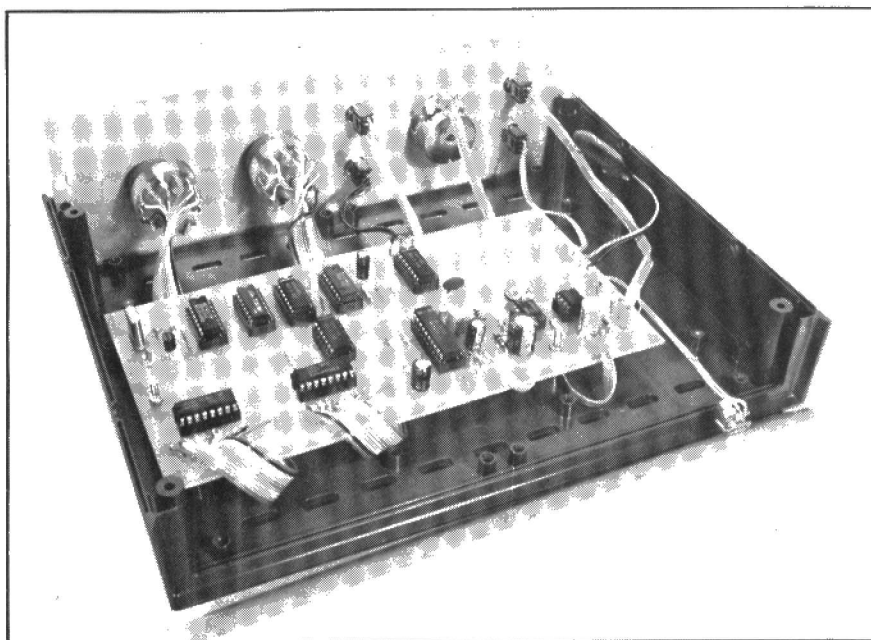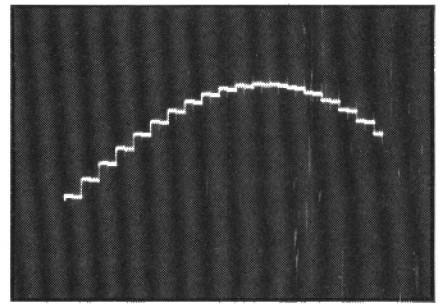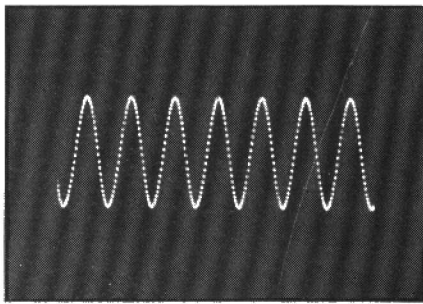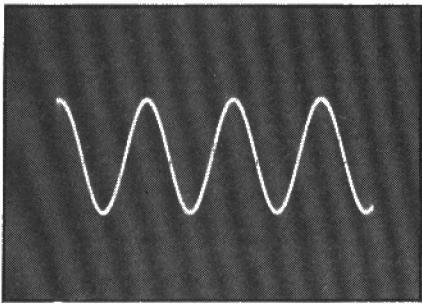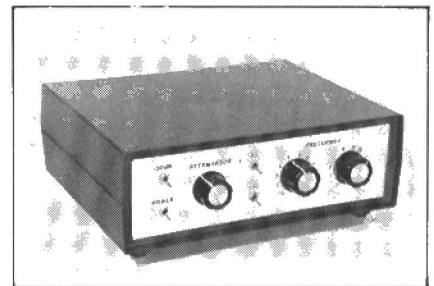
Typical waveform oscillograms
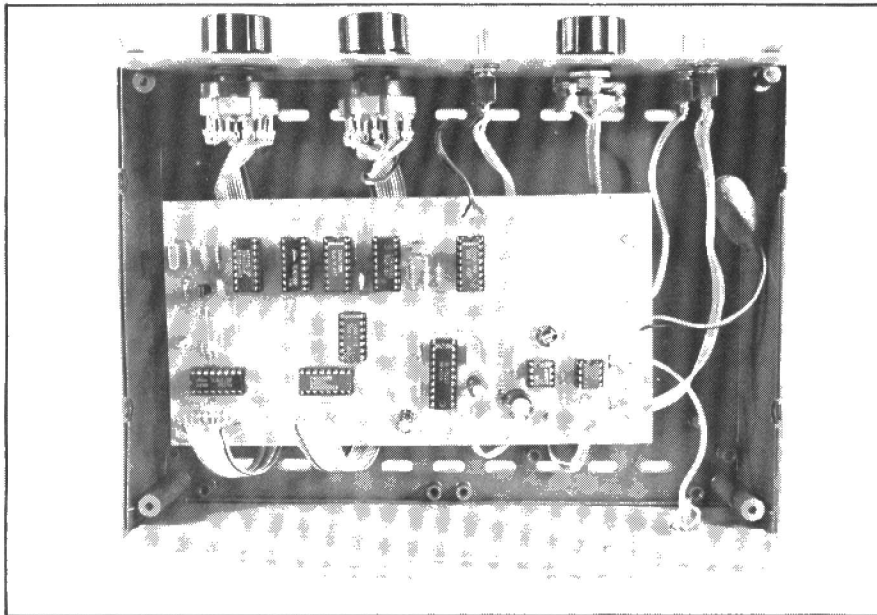
Even if you do not usually go to the trouble of marking front panel legends on projects, in this case the unit will be very difficult to use unless the four switches that control the output frequency are fully and clearly labelled. This is not too difficult to do using rub-on transfers, and is well worth the effort.
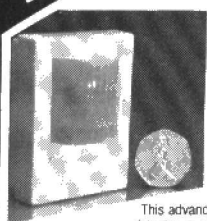
PE

FREQUENCY SYNTHESISERS

USUALLY ASSOCIATED WITH RADIO FREQUENCY SYNTHESIS PLAYS MANY OTHER ROLES

BY R.A. PENFOLD

Frequency synthesisers are one alternative method of producing signals at a desired set of frequencies, whether for test purposes or for use in a musical instrument. They have advantages and disadvantages which must be taken into account when designing circuits. Here we look at some of them.

FREQUENCY synthesisers are probably most closely associated with the world of radio, and in particular with scanning receivers and fancy looking communications equipment with high price tags. However, they are not limited to communications purposes, and find application in electronic music, test gear, and probably many other spheres of electronics as well. These synthesisers fall into two broad categroies; the type which provides a series of output frequencies that are well and unevenly spaced out, and the kind which has a large number of closely and evenly spaced output frequencies covering what is often a relatively narrow frequency band. With this second type there are often several ranges so that a wide range of frequencies is covered overall, with a massive number of output frequencies available in total.

The first type of frequency synthesiser is a relatively simple type, and it generally takes the place of a series of oscillators, or a single oscillator having several switched frequency selective feedback networks. The second type acts as a replacement for a standard variable frequency oscillator (v.f.o.).

ADVANTAGES

So why bother to use frequency synthesis in place of traditional circuit techniques? Taking the more simple type of synthesiser first, a common application would be as a calibration oscillator where (say) outputs are required at 10MHz, 1MHz, 100kHz, and 10kHz. One way of achieving the desired result would be to have a crystal oscillator having four switched crystals of the appropriate operating frequencies. This would be a relatively expensive way of doing things though, especially where low output frequencies are involved and very expensive crystals would be required. Using frequency synthesis techniques, all that is needed is a single oscillator at the hightest frequency required, with the synthesiser circuit then generating the lower frequencies that are required.

In electronic music applications frequency synthesis techniques can be used to produce a full range of musical notes and over a range of many octaves if required. This system has been used as the basis of many electronic organs and other instruments for some years

now, and although the circuitry involved may not be particularly simple, it is probably less involved than the alternative of having a separate oscillator to generate each note. Another point in its favour is that tuning requires the adjustment of just a single master oscillator, rather than individually adjusting each note. This makes initial setting up much faster and easier, as well as any periodic retuning that may be required. As any drift of one note will be matched by a drift of equal amount by all the others, the relative pitch is always correct, a factor which will often render any lack of pitch accuracy of comparatively minor importance. By using a crystal control in the master oscillator it is possible to obtain a very high degree of pitch accuracy without the need for any initial adjustment or retuning at all.

Variable frequency oscillators are used in the tuning systems of radio receivers, in AF and RF signal generators, etc., and in many ways they are very efficient. They are certainly quite simple by modern standards, even types with frills such as temperature compensation and highly stable supplies. Their main shortcomings are a lack of frequency stability, and problems with precisely setting the required frequency. There are methods of improving stability, but it takes a lot of effort and setting up to produce a design that is still substantially inferior to an average crystal oscillator in this respect. Accurate frequency setting can be achieved, but it again requires a lot of careful setting up initially, plus periodic checking and recalibration. It also usually involves an expensive precision drive mechanism and dial. Of course, a highly sophisticated drive and readout system is largely academic if the frequency stability of the oscillator is inadequate to jusify the resolution of the drive and dial, and there have been pieces of equipment which fall into this trap.

With frequency synthesis techniques the output signal has a frequency stability that is equal to that of the master oscillator, which in practice is

The YAESU FRG-8800. Its synthesiser and up-converter technique give continuous tuning from 150 kHz to 30MHz (plus keyboard tuning and automatic scanning).
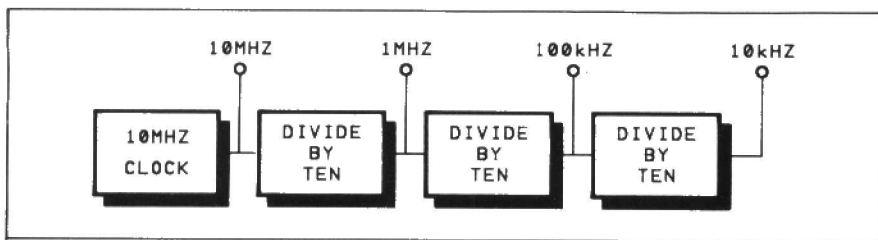
Fig.1. *Block diagram for a simple frequency synthesiser*

almost invariably a crystal type. This gives an output with very low levels of frequency drift, and the digital techniques ensure that the output frequency can be set very precisely without the need for complex setting up and frequent recalibration.

DRAWBACKS

Although frequency synthesisers have a lot in their favour, they have not completely ousted traditional frequency generator circuits, and are not without some drawbacks. With the simpler type the main problem is that it is not always possible to generate the set of frequencies that are required. They are produced from the master oscillator by a simple frequency division technique, and the required frequencies can only be produced precisely if they are all dividends of a practical master oscillator frequency. Otherwise a different form of frequency generator has to be used, or compromises over the accuracy of some of the output frequencies have to be accepted. Apart from this limitation this type of synthesiser represents a relatively inexpensive way of obtaining a range of accurate output frequencies, and is almost certain to be the most cost effective solution in the instances where it is applicable.

The main drawback of the second type of frequency synthesiser is that it is still very much more costly than a variable frequency oscillator. Special integrated circuits for this type of synthesiser are available, and these can help to ease the cost as well making the task of designing what is a fairly complex system very much easier. Synthesisers of this type are still far from cheap though, and custom chips are not available for every conceivable application for a circuit of this type. Possibly things will eventually progress to the point where a frequency synthesiser can be used as easily as a simple v.f.o., but this seems some way off at present.

Another drawback of these circuits is that they have limited resolution. With an ordinary v.f.o. there is, theoretically at any rate, infinite resolution, and any desired frequency can be set with absolute precision. In practice the mechanical side of the system will place some limitations on the resolution, but it would normally still be extremely high. With a frequency synthesiser it is poss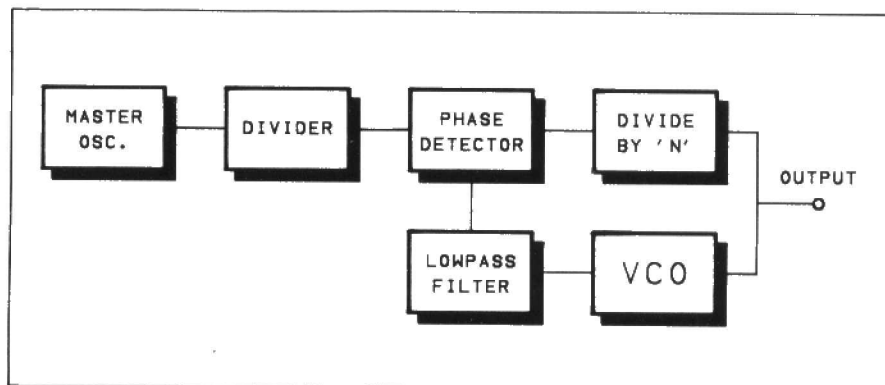ible to obtain very high resolution, but the greater the resolution the more complex the system becomes, and the more difficult it becomes to control and display output frequencies.

The importance of good resolution depends very much on the precise application. In the case of something like an ordinary broadcast receiver or a citizens band radio it might seem that very high resolution would be needed in order to permit accurate tuning of stations. In practice this is not the case as a system of channels is adopted, with stations therefore being spaced at regular intervals down the band (10kHz channel spacing in the case of the U.K. 27MHz FM citizens band for example). The resolution of the system then only needs to be equal to the channel spacing, provided of course, that the system is designed to produce the right output frequencies with good accuracy.

Not all applications require nice convenient output frequencies which are well suited to this form of frequency hopping. With something like a general coverage short wave receiver it might be necessary to tune to any frequency within the 1.6 to 30MHz frequency range. In particular, single sideband (SSB) signals are especially difficult, as the tuning needs to be within about 50 Hertz of the correct frequency if a reasonably intelligible audio output signal is to be obtained, and the tuning should preferably be within about 10 to 20 Hertz of the correct frequency. This is a tall order, with around one million output frequencies being needed in order to cover the full frequency range with good resolution. It is not impossible though, and a few hundred pounds will buy you a receiver that can do it.

CONFIGURATIONS

The simplest type of frequency synthesiser is the divider type, as outlined in the example configuration of Fig.1. This is a popular set up for crystal calibration oscillators, and it simply consists of a 10MHz oscillator plus a chain of three divide by ten counter circuits to provide additional output frequencies of 1MHz, 100kHz, and 10kHz. This arrangement can be extended if necessary, and it does not need to take the form of a simple series of divider circuits. Branches can be added to permit awkward frequencies to be produced without rendering lower frequencies further down the chain impossible. In an electronic music application a special divider circuit (appropriately called a "top octave generator") is used to produce a full range of semitones at the highest octave that is required, and then each of these tones is fed to a chain of divide by two flip/flops which generate the notes for the lower octaves. This requires dozens of divider stages, but integrated circuits designed specifically for this application make this system much more practical than it would otherwise be.

This arrangement is unsuitable for many applications as it is rather restrictive as far as the available output

Fig.2. *The standard frequency synthesiser arrangement*

frequencies are concerned. Frequencies can only be produced if they can be obtained by dividing the initial frequency by an integer. Also, the available frequencies are not evenly spread out, but are instead widely spaced near the beginning of the chain, with the spacing becoming less and less further down the chain. This suits some applications, including calibration oscillators and musical instruments, but it is totally useless in many others.

The system shown in the block diagram of Fig.2. is a much more versatile one, and it is the general type that is utilized in radio and similar applications. It is based on a phase locked loop (p.l.l.), and a conventional p.l.l. is formed by the phase detector, lowpass filter, and voltage controlled oscillator stages. The function of a phase

locked loop is to lock the voltage controlled oscillator onto the same frequency as, and in phase with, an input signal. It is achieved by comparing the two signals using a phase detector, and smoothing the output pulses from this circuit with a lowpass filter to generate a d.c. control voltage for the voltage controlled oscillator. Things are arranged so that if the oscillator is too high in frequency or ahead in phase, the output voltage from the lowpass filter is reduced. If it is low in frequency or lagging in phase, the output voltage from the lowpass filter increases. By a simple negative feedback action this keeps the voltage controlled oscillator quite accurately on the same frequency and in phase with the input signal, provided the latter stays within the tracking range of the circuit.

In this case the input to the phase locked loop is a reference frequency, and this would normally be at a fairly low frequency, as it must be equal to the required resolution of the circuit (assuming that the final output signal is not obtained via any divider circuits, as is sometimes the case). This reference signal is often generated by a crystal controlled master oscillator followed by some divider stages to give the required final frequency. This is not essential though, and depending on the application, it could be generated directly by a crystal oscillator, or even using a simple L-C or C-R oscillator. If the potential accuracy and stability of the system is to be properly realised though, a crystal oscillator is required.

If we ignore the divide by 'N' stage for a moment, the output frequency will simply be equal to the reference frequency. If we now take into account the divider circuit, and assume that it is a straightforward divide by two stage, the phase locked loop will still try to track the input signal, but it is the output from the divider circuit and not the voltage controlled oscillator that it tries to match to the input signal. In other words, to provide lock, the oscillator must be at twice the input frequency. With 'N' equal to three the oscillator goes to three times the reference frequency, with 'N' at four times the oscillator is locked at four times the reference frequency, and so on. The output of the voltage controlled oscillator can therefore be set to any multiple of the reference frequency simply by setting 'N' to the appropriate figure.

In practice things are not quite this simple as the phase locked loop will not have an infinite locking range, and there will be strict limits on the maximum and minimum frequencies that can be attained. If a very wide output frequency range is needed it is consequently necessary to have the voltage controlled oscillator cover this range in two or more bands. This can be achieved with the aid
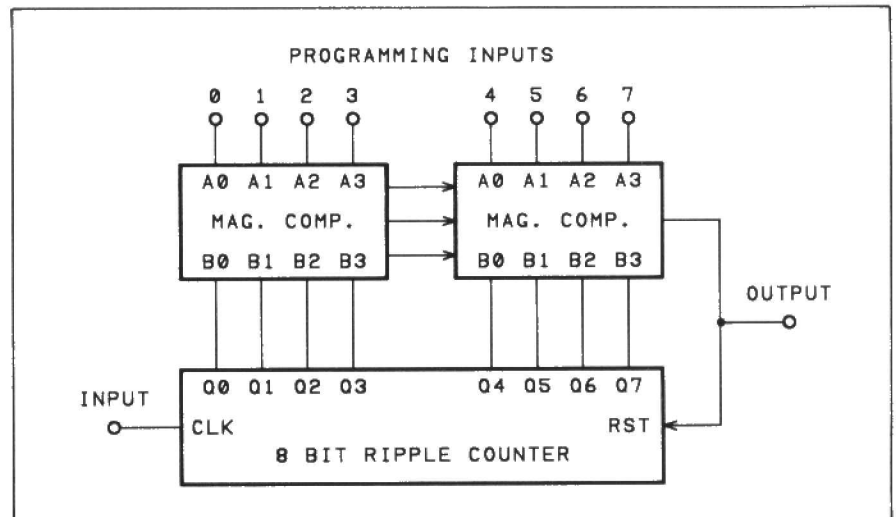

Fig.3. *A divide by 'N' system based on a binary ripple counter*

of solid state switching though, and to the user it might appear as though the frequencies are covered in a single range. This is certainly the case with some modern communications receivers which tune through the long, meduim, and full short wave bands continuously, with perhaps the slightest of glitches as the boundary from one range to another is crossed.

With superheterdoyne receivers the frequency covered by the v.f.o. is not the same as the frequency coverage of the receiver, as there is the intermediate frequency offset to consider. A popular technique with modern recievers is so called "up conversion", where the first I.F. is at a high frequency of around 45MHz or more. In order to achieve this, the oscillator must tune over a range of around 45MHz to 75MHz to give a difference frequency at the 45MHz i.f. and cover a 0 to 30MHz range. Although this is a frequency range of 30MHz, at these high frequencies it represents a span of under one octave, and it can be covered in a single range using a frequency synthesiser or a conventional v.f.o.

'N' DIVIDER

Where a modest number of output frequencies are required, it is possible to have a fairly simple divide by 'N' circuit with the division rate controlled by a switch or switches. Where a vast range of output frequencies are involved the divider is normally controlled by a microprocessor or some other fairly sophisticated digital control circuit. A microprocessor can control the divider (and hence the output frequency) under software control, or under manual control via a numeric keypad or a converntional rotary tuning type control. This type of tuning control is only a conventional type superficially, and the knob actually operates either an electro-magnetic pulse generator or an optical type. Actually two sets of pulses are generated, and the phasing of these

indicates to the control circuit which way the knob is being rotated. It then increases or decreases the division rate accordingly.

DIVIDERS

Although the system shown in Fig.2. looks very simple, in practice there are a few problems which have to be overcome. One of the simpler ones is that the output from the voltage controlled oscillator in a normal phase locked loop is either a squarewave or a triangular signal, but most frequency synthesiser applications require a reasonably pure sinewave. In radio frequency applications the oscillator is usually a fairly conventional L-C sinewave type with variable capacitance diodes to provide votage control, and a trigger circuit to give a squared output to drive the phase comparator (which is often a form of exclusive OR gate). In an audio application, probably the most common approach is to use a tracking filter to convert a square or triangular waveform to a reasonable sinewave signal.

A more serious problem is that of providing a divide by 'N' action. There are standard TTL and CMOS logic chips which provide a programmable divider action, and these can be used in conjuction with mechanical switching, or under electronic control via electronic switches. A more common approach though, is to use an arrangement of the type shown in Fig.3, which is based on a magnitude comparator and a binary divider. In fact two 4-bit magnitude comparators in series are used in the set up of Fig.3, and it is generally less expensive to use a chain of 7485 (or similar) 4-bit types than to have a design based on (say) 8-bit magnitude comparators.

Magnitude comparators are perhaps not the best known of logic building blocks, but they are extremely useful devices that are quite simple in principle.

The binary number on the 'A' inputs are fed from BCD switches, or the output from a microprocessor parallel port, and are set to the same value as the required division rate. The 'B' inputs of the comparator are fed from the outputs of the binary counter.

The basic action of the circuit is for the input signal to increment the binary counter until the magnitude comparator detects that the two input values are equal. It then resets the binary counter, which increments from zero again until the two sets of inputs reach the same states once more, whereupon the counter is reset, and so on. The reset pulses to the counter are at the input frequency divided by 'N', and this represents the output signal. The output signal is in the form of very brief positive pulses which may not suit the subsequent circuit. This can be overcome by using some form of pulse stretcher, such as a monostable multivibrator or a divide by two flip/flop. The latter is probably the best solution, although the system must then be designed to take into account the fact that it provides a divide by two action and halves all the output frequencies.

1 that the counters must be reloaded from the programming inputs, and the internal zero detection circuits must be augmented by an external '1 detector' gate circuit which monitors the outputs of the least significant counter. The action of the circuit is therefore to count down from the loaded value to 1, a pulse is then generated on the "PRESET" inputs, the counters are reloaded, they then count down to 1 again, and so on, with the pulses fed to the "PRESET" inputs also consitituting the divided output signal.

The relatively simple decoding of this system enables a higher maximum operating frequency to be achieved than when using the ripple counter method. Circuits of this type can operate at frequencies of 20MHz or more using fairly fast logic devices, and LSI synthesiser chips using CMOS technology can achieve similar speeds with the aid of look ahead decoding. Of course, the output frequency of the synthesiser can be much greater than the maximum clock frequency of the divider circuit, since in most cases it is feasible to use a prescaler ahead of the divide by 'N' circuit.

tuning drive that suffered a severe case of "backlash", and would render accurate tuning virtually impossible. The response time can be increased by raising the cut-off frequency of the lowpass filter in the phase locked loop, but with a low reference frequency this would give an excessive ripple content on the control voltage to the v.c.o. In order to obtain an acceptably low level of noise on the output it is essential to have a well designed v.c.o. fed with a well smoothed control voltage.

With a low frequency synthesiser there is no real difficulty in overcoming this problem, and the system shown in Fig.5 almost certainly represents the easiest solution. This is basically just the same as the frequency synthesiser outlined in Fig.2 and discussed previously, but it has a divider circuit added at the output. With the example figures a 2kHz reference frequency is used, giving output frequencies from the v.c.o. at 2kHz, 4kHz, 6kHz, etc. However, the divide by one hundred action at the output reduces these frequencies to 20Hz, 40Hz, 60Hz, etc. Thus a resolution of 20Hz is achieved, but the phase locked loop can have a fast response time as it is operating at the relatively high frequency of 2kHz.

This system is less practical where output frequencies of many megahertz are required, since the v.c.o. and (more importantly) the divide by 'N' circuit, have to operate at frequencies which could well be a few hundred megahertz or more. This is actually quite feasible provided a prescaler is added ahead to the divide by 'N' circuit so that it is dealing with comparatively low frequencies. This is tolerable only if a fairly restricted output frequency range is acceptable.

Rather than use a prescaler to reduce the input frequency to the divide by 'N' circuit, in some designs the heterodyne principle is utilized. This requires only a simple addition to the standard synthesiser configuration, as shown in Fig.6. The output from the v.c.o. is mixed with the output from a high frequency oscillator, but here we are talking in terms of the type of mixer used in radio receivers, rather than a simple summing mode mixer as used in audio circuits. This type of mixer is really a form of modulator, and is essentially the same as the "ring" modulators that are used in electronic music. It therefore generates sum and difference output frequencies. If the output from the v.c.o. was at 100MHz for example, and an input to the divide by 'N' circuit at 20MHz was required, the high frequency oscillator could be set at 80MHz (100MHz − 80MHz = 20MHz) or 120MHz (120MHz − 100MHz = 20MHz). In either case the difference frequency is the required 20MHz output frequency. A bandpass or lowpass filter removes the sum signal.
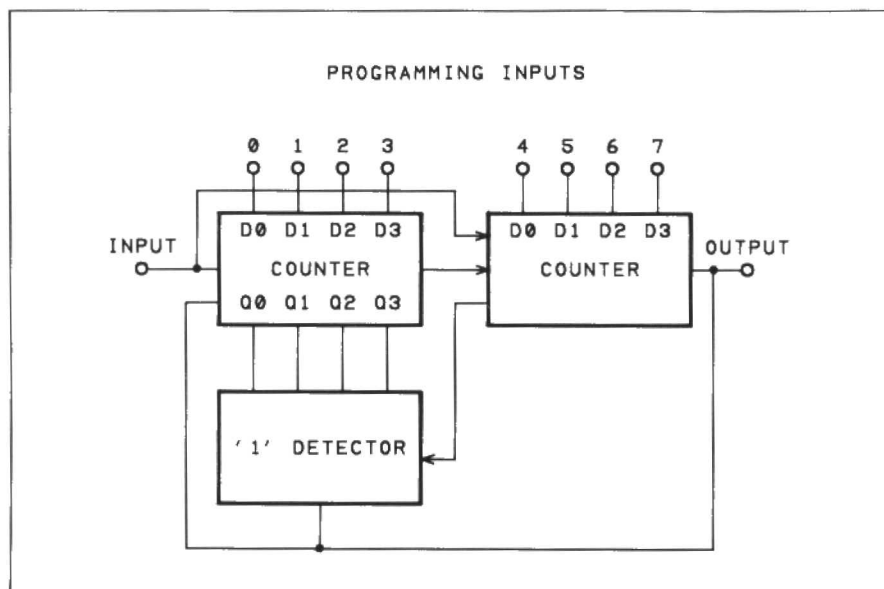

**Fig.4.** *A divider by 'N' arrangement based on synchronous down counters*

An alternative form of frequency divider, and one which is perferable for high frequency applications, is one that is based on a synchronous down counter. This set up is shown (in what is admittedly a rather over simplified form) in Fig.4. The required division rate is set up in binary fashion on the data inputs of the counters, which in this case consist of two 4-bit types cascaded to provide an 8-bit counter. The number is loaded into the counters which then count down until the value of 1 is reached. The counters have internal zero detection circuits which are used when cascading them, but in this case it is at a count of

QUICK RESPONSES

There is a problem with many frequency synthesisers in that they require good resolution, with perhaps 20 Hertz increments in the output frequency, but they must also respond reasonably quickly to changes on the programming inputs. With a radio receiver, for example, it would be no good having a manual tuning control where tuning down the band resulted in the set responding slowly and catching up after a few seconds, or even after around half a second. This would be like using a conventional receiver with a
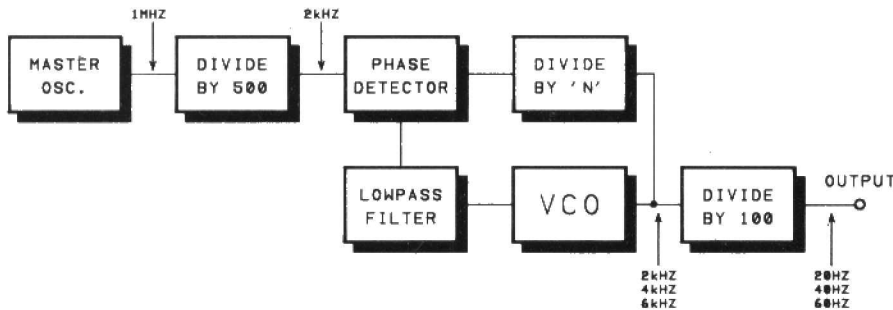
Fig.5. *The simplest method of obtaining good resolution together with a fast response time*
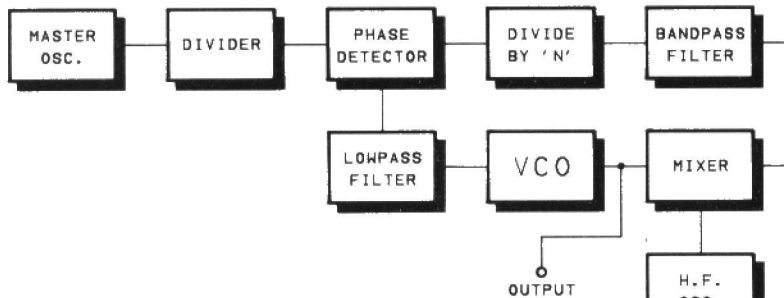
**Fig.6.** *Using the heterodyne principle to obtain a sort of prescaler effect.*

Circuits of this type are sometimes used in transceivers. There is a problem with transceiver v.f.o.s in that the transmitter requires a basic signal at the tranmission/reception frequency, whereas the receiver v.f.o. must be offset from this by an amount equal to the first intermediate frequency. If we take our earlier example with the high frequency oscillator at 120MHz, the 120MHz – 100MHz difference signal certainly gives the required 20MHz output signal. As we saw, the same thing can be achieved with the v.c.o. at 80MHz though (100MHz – 80MHz = 20MHz), and the circuit could lock into either state. In practice the v.c.o. must be designed so that only the correct frequency is within its range, but by switching one of its frequency selective components it is possible to switch from one to the other. This can be used to give the two output frequency ranges for transceiver use if the system is designed so that the difference between the two output frequency ranges is equal to the correct intermediate frequency offset.

In order to provide a high degree of resolution, together with a fast response time and a wide frequency range, some synthesiser designs have quite complex configurations with multiple phase locked loops and heterodyning being used. A typical arrangement is shown in the block diagram of Fig.7. The top set of blocks form a conventional synthesiser, and this provides coarse tuning with the output frequencies being spaced at around 50kHz to 500kHz. The fine tune synthesiser is of the type shown in

Fig.5 and described earlier, but using a prescaler to give an output at a frequency of a few megahertz with very fine resolution and fast response time. It has only a very restricted fre-quency range though, of about 50kHz to 500kHz (to match the resolution of the coarse tune synthesiser).

The main synthesiser (the blocks in the bottom right hand part of the diagram) is basically of the type shown in Fig.6 and described previously, but there is no divide by 'N' circuit. Instead, heterodyning is used to match the v.c.o. frequency to the reference frequency from the fine tuning synthesiser. As a result of this, incrementing the reference frequency in (say) 20 Hertz jumps increases the output frequency by the same amount. The absence of the divider circuit is essential here, as it would effectively multiply the jumps in frequency from the fine frequency synthesiser, and prevent the desired action from being obtained. This also means that as the frequency from the coarse tune synthsiser is shifted up and down, the output from the unit varies by exactly the same amount, again giving the required action from the system.

There is no potential flaw in this configuration in that, as pointed out earlier, with the heterodyne system of
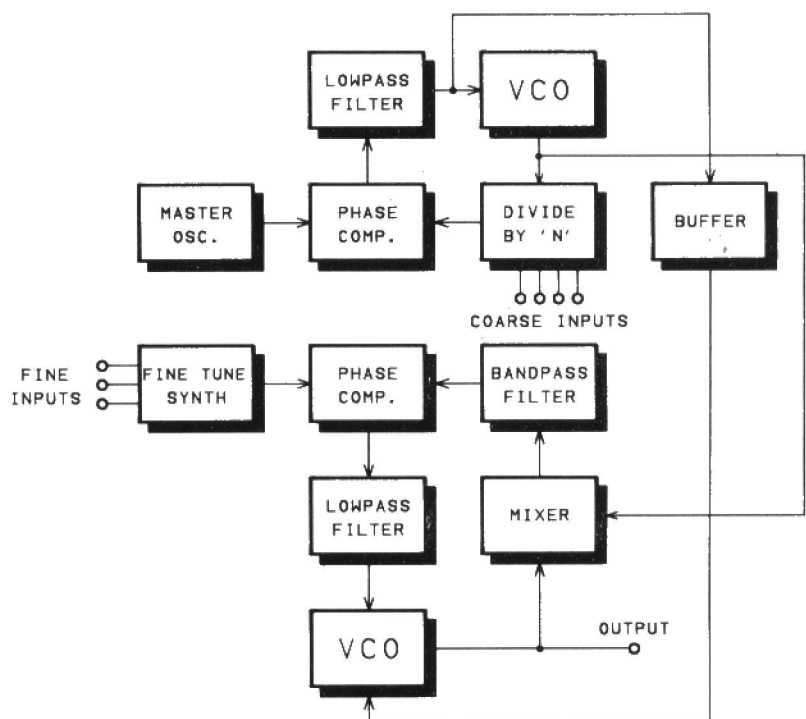
Fig.7. *A complex synthesiser configuration that is based on multiple loop and heterodyne techniques*

prescaling there are two output frequencies that will give the correct input frequency to the phase comparator. In this case the wide operating frequency is likely to result in both of these being within range of the v.c.o. In order to prevent the circuit from locking on to the wrong output frequency, the control voltage from the coarse tune synthsiser is buffered and fed to the main v.c.o. This takes the main v.c.o. to roughly the right frequency, with the phase locked loop then being used to keep it precisely locked.

CONCLUSION

Although they are still not really commonplace electronic circuits, frequency synthesisers have gradually become more widespread over the past few years, and are now to be found in many types of radio equipment, and in one form or another they can be found in many other types of electronic equipment. With LSI integrated circuits becoming less expensive, special synthesiser chips will probably make this type of circuit a practical proposition in an ever increasing range of applications, and result in their introduction into low cost equipment. Perhaps the biggest obstacle to their use, particularly in radio applications, is the large amount of radio frequency interference (r.f.i.) that is generated by the synthesiser circuits themselves, and also by any digital control circuit that is used. Microprocessor controllers are particularly good at generating r.f.i. Heavy screening of the relevant circuitry is acceptable for something like a communications receiver, but is less than ideal for a pocket radio. No doubt a solution to the r.f.i. problem will be found in due course. **P.E.**
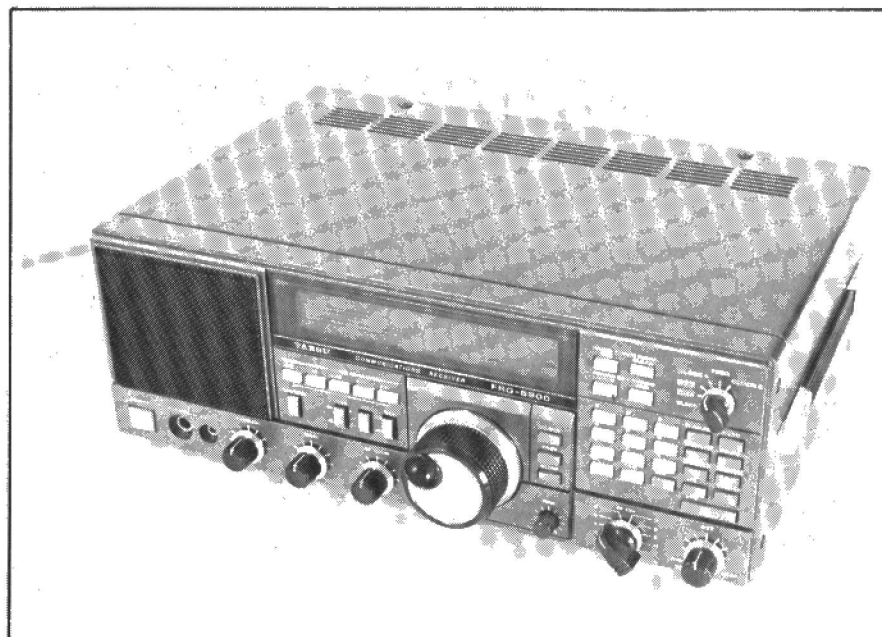
NOW YOU'VE READ THE THEORY, PUT IT INTO PRACTISE BY BUILDING THE SYNTHESISING AF GENERATOR ON PAGE 12.

Nearly everyone is familiar with the principles of television functioning, but in the last five years many of the details have changed subtlely, brining in advances such as frequency synthesis in place of manual tuning and SAW filters in place of LC filters.

MODERN TELEVISION RECEIVERS

TELEVISION HAS BECOME MORE EFFICIENT BEHIND THE SCENES

BY MIKE SANDERS

IT IS a tribute to modern technology that television receivers have not increased much in cost over the last ten years. In fact, if inflation is taken into account, the price has probably decreased in real terms.

The widespread use of integrated circuits has led to more sophisticated signal processing. This has probably not achieved or improved the picture quality, only clever ways of doing the same thing. Sophisticated methods of automatic correction have delayed defects due to component ageing. In particular, frequency synthesis for signal tuning (as for video recorders) has largely replaced manual tuning.

We shall take a brief look at developments over the past five years or so in all aspects of receiver circuitry. A television receiver may be thought of as consisting of three parts: the power supplies, the horizontal and vertical scanning, and signal processing.

POWER SUPPLIES

Power supplies required in a colour television receiver range from as low as 5V for driving ICs to as high as 25kV for the final anode. Thyristor controlled power supplies have been used since the first generation of solid state receivers, and have continued in use to this day, with some modifications.

Although the first thyristors operated on a half wave mains rectified output, the use of a thyristor after a full wave rectifier is preferred by the UK Electricity Board. This reduces the amount of d.c. and harmonics fed back into the mains. It is also easier to smooth a 100Hz ripple than to smooth 50Hz. However, one of the main disadvantages of a full wave bridge rectifier without an isolating transformer is that the chassis is live, regardless of which way the mains is connected.

The thyristor switch has two main drawbacks: it is not isolated from the mains and it has a 50Hz ripple. Filtering this ripple leads to an expensive choke as well as heat dissipation.

Fig.1.
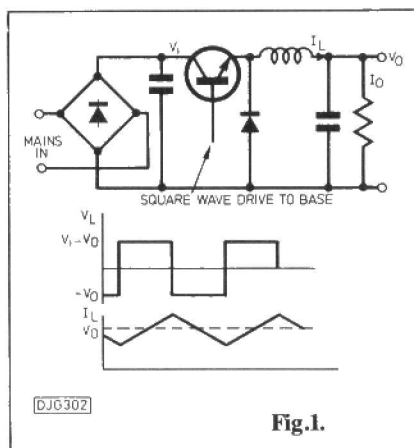
Instead, if we switch the control circuitry at a much higher frequency, we can reduce both problems. Such circuits are called switched mode power supplies (SMPS).

There are two main types of SMPS, the series on forward converter with the choke in series with the load and the parallel or flyback converter where the choke is in parallel with the load. Fig. 1 shows the series converter and the voltage and current waveforms across the choke. Fig. 2 shows the parallel converter.

Fig.2.
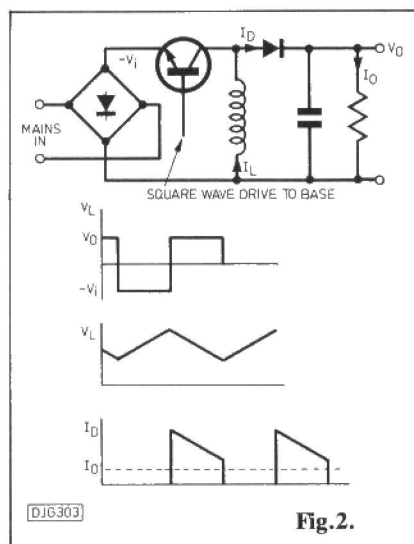
These circuits operate at line frequency or a multiple of line frequency. The input is rectified mains (i.e. virtually d.c.) and the output is d.c. so the circuits are d.c. to d.c. converters. In both instances the square wave drive is applied to the base of the control transistor.

The advantage of synchronising the power supply with the line timebase is that the SMPS wave can now drive the line output transistor. Also, beat frequency interference is prevented from entering the power supply.

Fig.3.
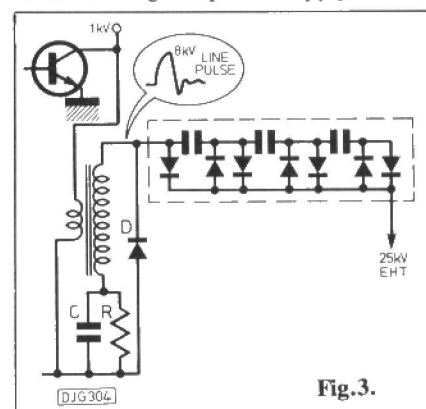
EHT GENERATION

There are two main methods of generating the extra high tension voltage (eht): a transformer with several secondary windings with diodes to charge the interlayer capacitance, or a transformer with an 8KV overwind to drive a tripler and produce the required 25KV.

A voltage less than 25kV would produce a poor colour picture, while voltages higher than 25kV would lead to flashovers, insulation breakdown and X-ray radiation.

The straight forward method of rectifying a sine wave is avoided since the rectifiers would require a peak inverse voltage of twice the desired voltage. Instead, the above methods rectify low duration pulses and the peak inverse voltage of the diodes need be no higher than the desired voltage.

Fig.4.

DIELECTRIC

FOIL
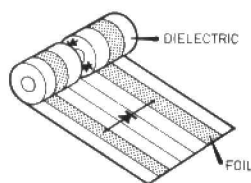
DJG 305

Fig. 3 shows how a tripler is employed in an eht circuit and Fig. 4 shows the construction of a tripler. Formerly a tripler was made up of discrete diodes and capacitors but the present technology rolls the diodes between the layers of tin foil for the capacitors. This package is not only reliable but can be produced again and again with the same parameters. In Fig. 3, the components, C and D, damp any overshoot of the line pulse.

SCANNING

The scanning requirements have not changed. However, scanning systems have become simpler with the development of self convergent coils. The energy requirement has also been reduced. For instance, the Mullard 30AX tube consumes 1.8W for vertical deflection compared to 2.9W for the 20AX tube.

The power for horizontal deflection has also been reduced from 5.6mJ to 4.7mJ. Not significant, one might say in terms of energy saving, but quite significant in helping to reduce the temperature of the receiver, since television sets dissipate a lot of heat.

The basic circuit for line deflection is shown in Fig. 5. This circuit may also be used to provide power to the field timebase, and timing for blanking and gating.

The usual 'S' correction and pincushion correction needs to be provided. The first is supplied by capacitor C in Fig. 5, and pincushion distortion can be corrected by modulation of the line scan amplitude. But the flyback waveform must not be modulated or the pulses and other derived supplies would also be modulated at field rate.

Diode modulators do the job well by modulating the current through the line deflecting system and since the line transformer voltage is kept constant, the

above mentioned nasties are avoided.

Two types of diode modulator are in use, the high and low voltage types. The diodes in the low voltage type operate at scan voltages. In the high voltage version, one of the diodes is an energy recovery device.

Fig.5.

SUPPLY

C

LINE DEFLECTION COILS

0V
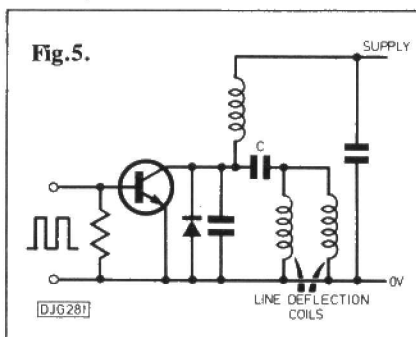
DJG281

THE TUNER

There are two main demands on a tuner: selectivity and dynamic range. Selectivity means receiving the required signal and rejecting everything else. Dynamic range is related to the amplitude of the signal, i.e. the receiver must be able to receive weak signals without being overloaded by strong signals. Clearly some form of gain control is required.

The evolution of the tuner is interesting. The earliest ones employed a ganged rotary capacitor with fixed inductors. Then came the mechanical push button selectors. The present method is to use varicap diodes which are electrically controlled.

In addition, some television receivers employ frequency synthesisers, as do video recorders. Channel frequencies are stored in a read only memory until called up and associated with the

required transmitting station. Other frequency synthesisers employ an incremental tuning which hunts through the UHF band, stopping when a signal is detected to give the customer the opportunity to accept or reject it.

The 3dB points of a tuner are about 10MHz to 20MHz and the earliest varicap diodes were controlled by altering the emitter current of the RF transistor. Later, a grounded base RF transistor was used with a pin diode to control the input gain. Present tuners use a tetrode MOSFET, Fig. 6. D2, D3 and D5 are the varicap diodes and L10, L11 and L14 the tuned inductors. TR1 is the tetrode MOSFET operating at 10mA drain current. D4 is the mixer diode and a socket supplies an oscillator sample for frequency synthesis.

IF FILTERS

Television broadcasting stations employ vestigial sideband transmission, i.e. both sidebands up to 1MHz, and upper sideband only, above 1MHz.

The IF vision carrier is at 39.5MHz, sound carrier at 33.5MHz and colour sub-carrier at 35.1MHz. The vision carrier of the adjacent channel is at 31.5MHz, and the sound carrier of the other adjacent channel is at 41.5MHz. Therefore suitable traps need to be inserted as in Fig. 7.

Fig. 8 shows an acceptable IF response, and a sound shelf is employed so that the sound carrier does not change in amplitude if the IF drifts slightly.

The earliest circuits used a cascade of tuned stages which required delicate tuning. Then came integrated circuits which provide lumped gain, and computer aided design provided lumped filters. However, the introduction of

Fig.6.
Circuit of Mullard U341 LO Tuner

OSCILLATOR SAMPLE SOCKET

AERIAL SOCKET

DJG307

2 +12V R.F. SUPPLY VOLTAGE

3 +9·2V TO +1V A.G.C. VOLTAGE

4 +1V TO +28V TUNING VOLTAGE

6 +12V SUPPLY VOLTAGE OSCILLATOR

7 I.F. INJECT

10 I.F. OUTPUT

Fig.7.
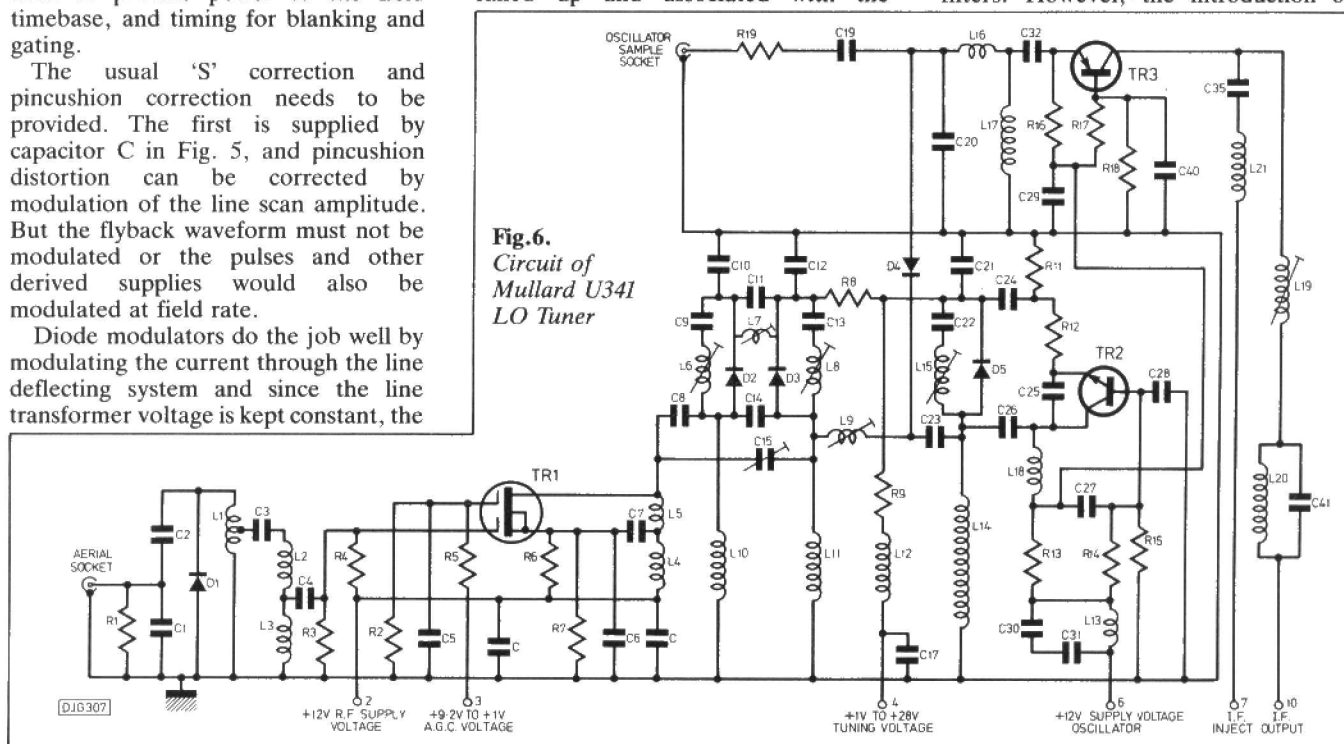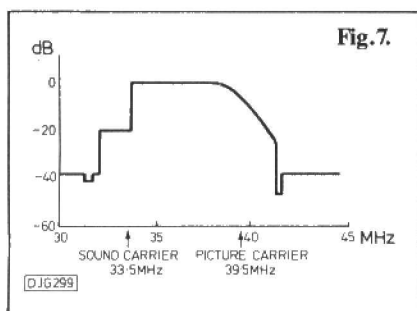
Teletext means that there is an even stricter requirement for a linear phase response and designers have turned to surface acoustic wave (SAW) filters.

SAW filters introduce a loss of about 10dB higher than conventional LC filters so an amplifier is required before the filter or the signal to noise ratio may be degraded. SAW technology is good up to 1GHz and employs a piezo-electric material as a substrate, Fig. 9. On this are mounted the transmitter and receiver which are in the shape of interleaved combs. The signal propagates through the lithium niobate crystal and the required response is obtained by suitable design of the crystal as well as combs.

Fig.8.

Fig.9.
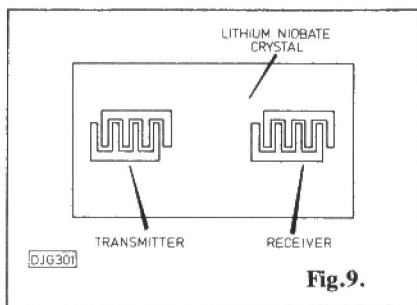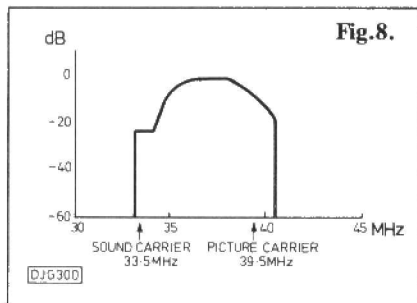
AFC, AGC AND NOISE INVERSION

Automatic frequency control (AFC) is essential to keep the receiver locked to the transmitted signal. The tuning may drift because of components in the receiver, or due to external causes, e.g. an aircraft crossing the signal path.

IF demodulators, like the TDA 3540 and TDA 3541, include circuits for correcting frequency drift as well as providing automatic gain control (AGC). The first IC is used for npn type RF stages, and the TDA 3541 for the pnp type RF stages.

Although the AGC holds the signal fairly constant, it cannot respond to

noise spikes. Such spikes would interfere with synchronisation in the black (negative) direction of the signal, or drive the tube hard, causing white spots in the peak white (positive) direction, Fig. 10.

The IF demodulator chip therefore includes a noise inverter. As soon as the threshold is reached in either direction, the noise inverter returns the signal to the level it was at before the spike. For a negative going spike it also kills the AGC detector temporarily so that the AFC level does not go to pot.

Fig.10.
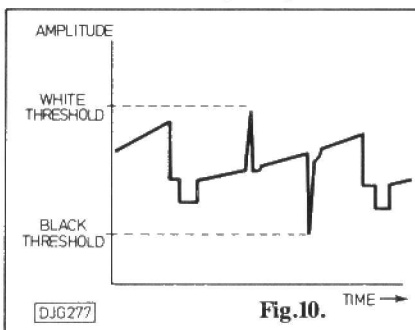
LUMINANCE

Processing of the luminance signal involves delay, brightness and contrast control, retrace blanking and black level clamping. The delay line is a wire, wound on a capacitive material. This is a low pass filter terminated in its characteristic impedance using resistors of 1Kohm to 2Kohm. This delay line produces a 6dB voltage loss.

In order to use a remote control for altering the brightness and contrast, the usual potentiometer on the set is of little use. Instead a variable gain stage is required with d.c. control.

The problem with varying the gain is that the black level is then altered. One of the best methods of clamping the black level is by means of a backporch keying pulse.

After the black level has been clamped, the retrace blanking needs to be inserted and must be of the same duration as line flyback.

Fig.11.
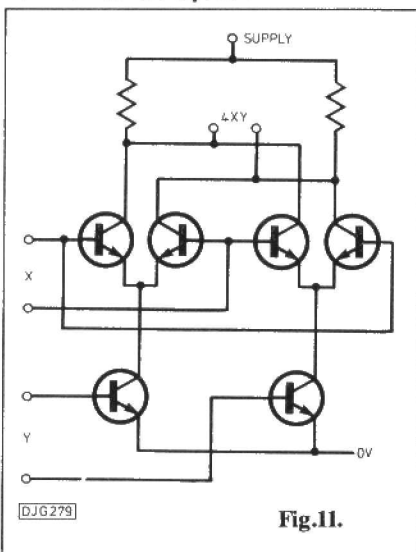
COLOUR DECODING

From the IF demodulated output, the luminance signal and 6MHz intercarrier sound are extracted, leaving the colour burst and luminance subcarrier which is quadrature modulated.

Modern decoders incorporate an 8.8MHz subcarrier oscillator and divide by two circuits to produce two 4.4MHz reference signals at 90°.

The four quadrant multiplier, Fig. 11, is the basic circuit which is used a lot in modern technology, for both colour demodulation as well as phase detection. Applying signals of x and y to the input results in 4xy at the output, and is linear if x and y are less than ±0.5. The circuit operates on both the amplitude as well as the phase of the inputs.

A PAL delay line is made of a glass sheet with piezo electric transducers along the edges. These transducers act as transmitter and receiver and the acoustic waves are delayed 64μs. The delay line introduces a 9dB loss and has a 1MHz bandwidth at the subcarrier frequency. In order to produce the required delay, the sheet of glass must have precise dimensions and is ground under electric control to an accuracy of one wavelength of subcarrier.

RGB drive involves setting the black levels and where the drive is connected to the cathode of each gun, black level is set by adjusting the voltage on the first anode of each gun.

The modern technique is to use a dynamic method instead of the above manual method. The advantages of the dynamic method is that it compensates for the ageing of amplifiers and tubes.

In the dynamic method, three lines close to the end of field blanking are measured and stored. This is done for each colour close to cut off. The stored samples are then used for stabilising the d.c. level of each gun. TDA 3562A is one i.c. which incorporates black current stabilisation with colour decoding, and a complete circuit is shown in Fig. 12.

SYNCHRONISATION

Synchronisation is achieved by separating the sync pulses from the composite video waveform. From this, timing waveforms are obtained to drive a phase lock loop.

Although phase lock loops work well for line synchronisation, phase lock loops for field sync cause a delay in pull-in time after a channel change.

The simplest sync separator is a transistor with two time constants in the input, Fig. 13. A short time constant is required to avoid hum on the video content and a long time constant is required to avoid distortion of the field sync.

The modern method of achieving sync separation is obtained in i.c. form as TDA2571, TDA2576A and TDA2578. These have the advantage of not being
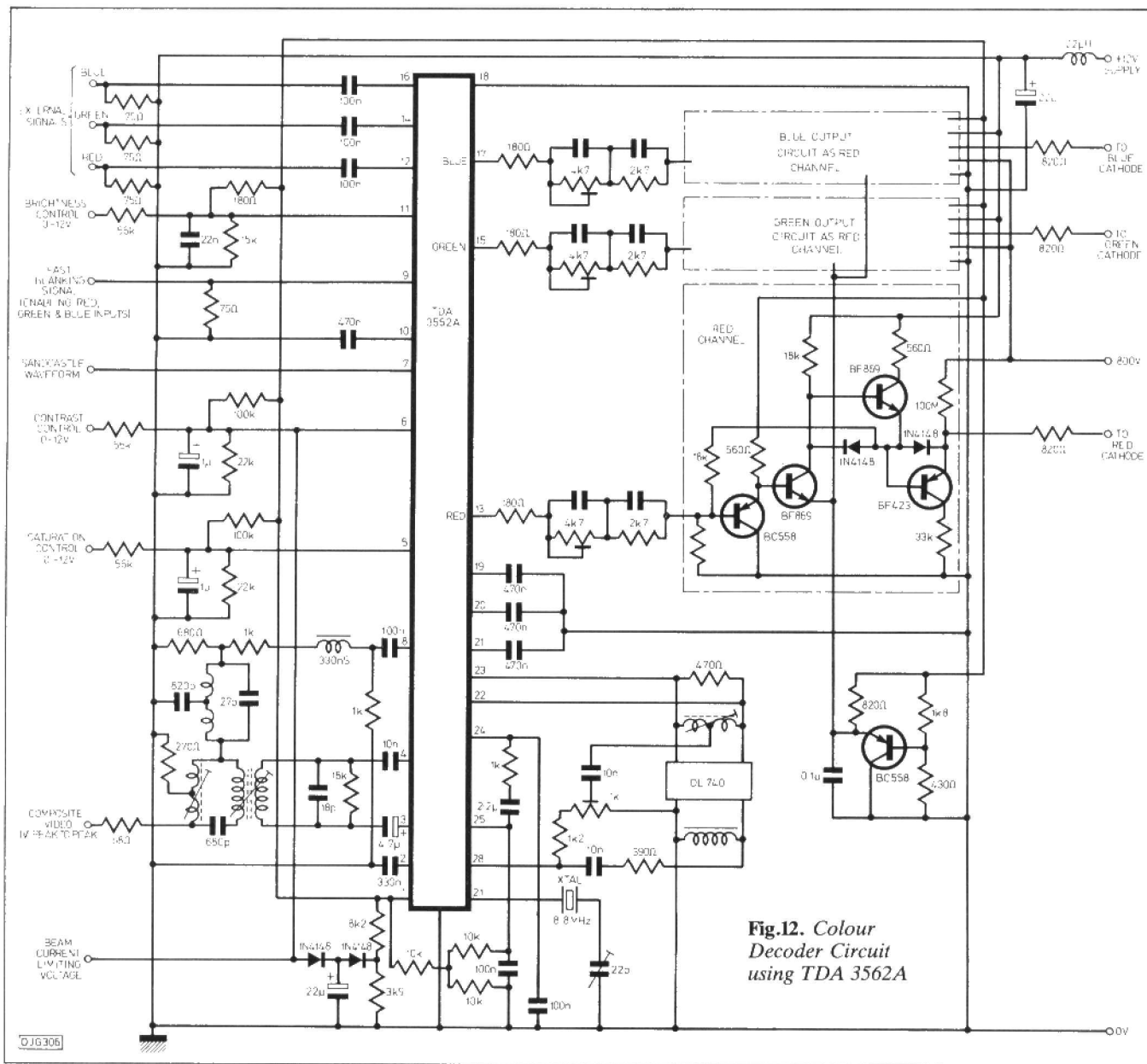
Fig.12. *Colour Decoder Circuit using TDA 3562A*

influenced by the video content as is the simple sync separator. These integrated circuits sense the video level and the sync peak, and slice in between. The result is a clean waveform without any video.

Phase lock loops have become quite sophisticated. For instance some have two operating speeds, fast and slow. Fast, say, for video recorder operation, and slow for other signals once initial lock has been obtained.

In addition, some receivers employ two phase lock loops. One to generate

Fig.13.

a back porch clamp and burst gating, the second to provide fine tuning on the first by using a phase comparator to stabilise the raster.

An astable multivibrator is usually used as the field oscillator and must be set to the centre of its catching range to compensate for ageing. Large pulses permit good synchronisation but also picks up noise. On the other hand, low level pulses are better able to withstand noise during scan, but provide only a narrow catching and holding range.

In a video playback mode sync pulses may be out by $\pm 20\mu S$ due to tape stretch and it is useful to switch to direct synchronisation. This can be done by means of a +12V flag when a video recorder is in playback.

The timing information from sync pulses is also required in the decoder sections. Early receivers generated these from a timebase, but modern receivers provide these from a single pin on a chip. Two types of integrated waveform are available, called a sandcastle waveform.

Fig. 14 shows a two tier sandcastle with burst keying and line blanking, and Fig. 15 shows a three tiered waveform. Fig. 15 has the two waveforms of Fig. 14 and field blanking in addition.

TELETEXT

Teletext uses the silent periods of field blanking to transmit information in binary form. Lines 7 to 32 and 320 to 335 are available, but only some of these are used at present.

A page contains 24 rows with 40 characters per row. Each character is encoded in 7bits, plus one parity bit. Binary 0 is within $\pm 2\%$ of black level and binary 1 is 66% ($\pm 6\%$) of peak white.

Each row carries quite a lot of control information: 16 bits for the data clock; 8 for frame coding; 16 bits for row address and control. The control bits determine the colours, spacings, height and flashing of characters etc.
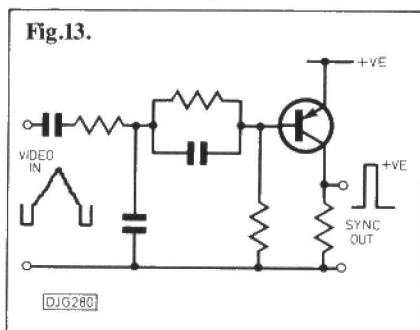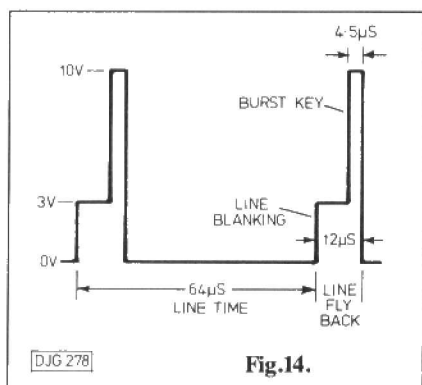
Fig.14.
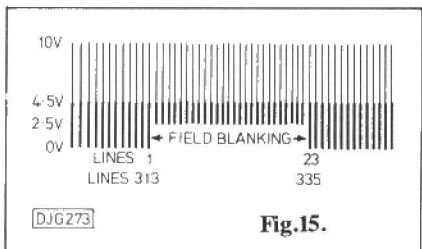
Fig.15.

Teletext transmission requires low quadrature distortion in the IF demodulator and constant group delay in the IF stages, otherwise intersymbol distortion would result. Hence the need for more precise devices like SAW filters.

The remote control uses either infrared or ultrasonic transmitters, typically employing 32 command keys.

The remote control (transmitter) sends out 12bits consisting of data (5bits) and a start code (7bits). The 12bits are also transmitted in complimented code and if this is not received as a mirror image of the first, the receiver will reject the command. This helps defeat any spurious interference.

Another method of defeating continuous interference, like line frequencies, is to use a mark space ratio of 66.6:16.6, i.e. a zero bit occupies 16.6% of the time compared to 66.6% for a 1bit.

FLAT SCREENS

The cathode ray tube is one of the last bastions of the valve era and although engineers would dearly like to replace it

with some kind of matrix addressed directly by semiconductors, there is nothing at present to beat the speed and efficiency of the cathode ray tube in addressing a large number of pixels (screen cells).

There are a number of limitations to providing large screen (say 75cm × 100cm) displays. Flicker around the perimeter appears to increase unless the field rate is also increased. The resolution also suffers since what is normally displayed on a conventional TV set is now enlarged by about four times.

Two main technologies have emerged for flat screen displays. One is the plasma discharge panel and the other is the flat CRT. Plasma discharge panels of around eight to twelve inches width are widely used on portable computers.

MOS integrated circuits with breakdown voltages of 250V have been used to address the screen cells. The gas plasma consists of a mixture of Helium and Xenon with the latter making up 0.5% to 2% of the volume. The structure of a typical cell is shown in Fig. 16, and the main limitation is low brightness.

The flat CRT is based on the electron beam waveguide where low voltages, around 100V, can propagate up to 1 metre at 99% efficiency. There could be as many as 500 electron guns positioned at the base of the 4in thick screen, Fig. 17.

The glass has to be about 6mm thick to withstand atmospheric pressures of 8 tons on each side and in addition, there are internal support structures. The beam is sent up the guide and −60V to −180V on the extract electrode addresses the required cell, Fig. 18. The beam guide forms a ladder mesh, therefore three of these are required for each of the colours and three modulators are also required.

Using these techniques brightnesses of 350cd/m² have been obtained for flat CRTs, compared to 700cd/m² for normal CRTs, and only 35cd/m² for plasma devices. The sizes of screen were approximately the same, about 22 × 25cm.
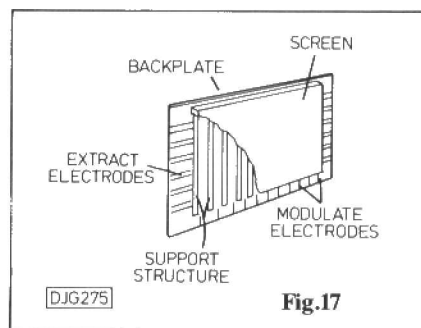
Fig.17

WORK OF THE CCIR

The International Radio Consultative Committee (CCIR) has been studying high definition television (HDTV) for the past four years. HDTV will use nearly twice the number of lines of today's systems. This will improve picture quality to that of 35mm film as used in the cinema. In addition, it will do away with the numerous analogue standards PAL, NTSC, SECAM and so avoid the need for interconversion between these standards.

CONCLUSIONS

We have seen how integrated circuits have provided gimmicks under the broad banner of signal processing: storage of black levels to compensate for electron gun ageing, frequency synthesis tuning, sandcastle waveform and generation etc. We have also seen how technology in other fields has provided SAW filters to meet the challenge of Teletext.

Flat screens are still under development and no doubt there will be a demand for such screens, not only for the flatness, but also for the larger pictures. Digital television will provide better signal to noise ratios and HDTV will provide better resolution. No doubt that all this will come to pass in the next five to ten years, so what next?

The ear perceives in a serial mode and is quite satisfied with stereophonic sound. But the eye perceives in a parallel mode and it may take three dimensional pictures to satisfy the eye. However, holography is another topic and still a thing of the future. **PE**
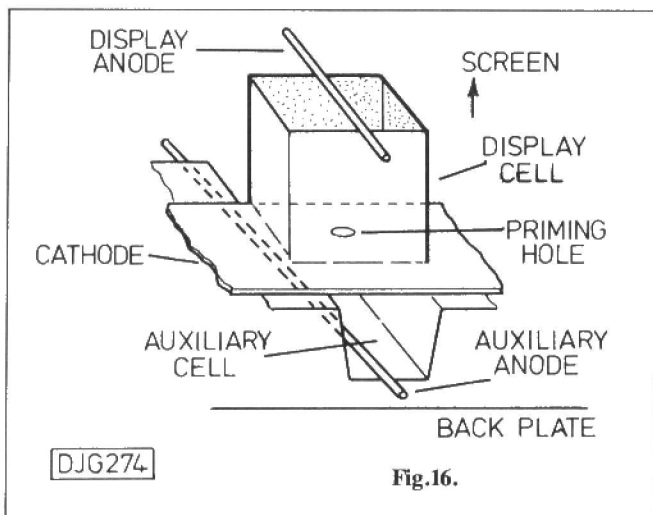
Fig.16.
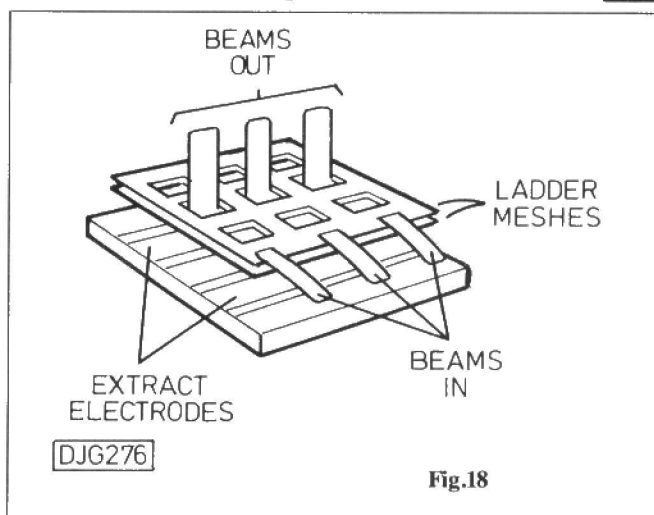
Fig.18
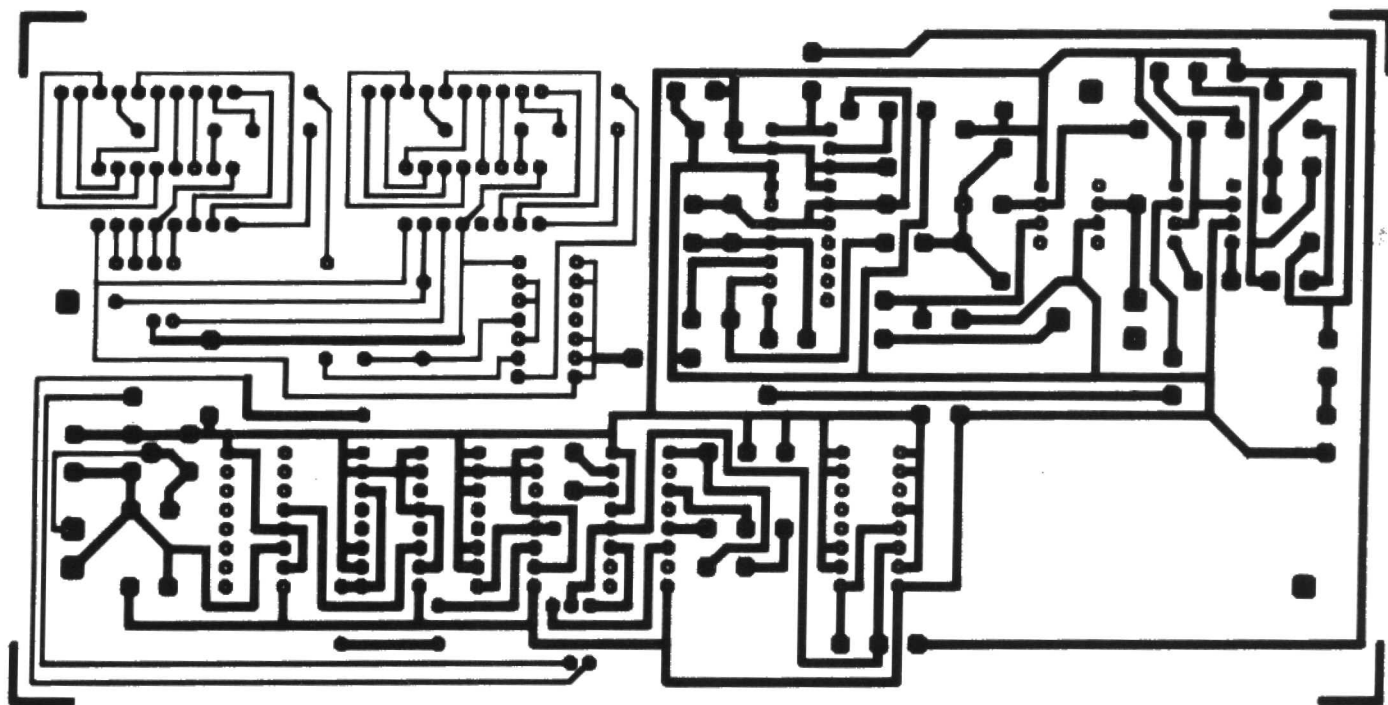
PE PCB 146. Synthesising AF Generator Board, available through the PE PCB Service.

HOW TO USE THESE TRACKS

FIRST MAKE TRANSPARENT COPY

(We regret that we cannot supply transparent copies of PCB track layouts.)

STUDIO COPY METHOD

Ask local photographic studio to produce high contrast 1 to 1 positive transparency.

HOME PHOTOGRAPHY METHOD

Using even, bright illumination, photograph track onto fine grain black and white negative film. Develop film for high contrast. Photographically enlarge image up to lifesize, and print onto high contrast lithographic cut film, such as Agfa Copyline HDU 3P Type 2. Develop in Agfa Litex G90T litho developer, or similar.

PHOTOCOPY METHOD

Ask local photocopy shop to make a good contrast copy onto acetate film.

(Some copiers are better than others – shop around.) Then touch up tracks with dense black ink, or photographic opaque ink.

ISODRAFT METHOD

Have a normal photocopy made, ensuring good dense black image. Spray ISOdraft Transparentiser onto copy in accordance with supplied instructions. **ISOdraft** is available from **Cannon & Wrin,** 68 High Street, Chislehurst, Kent. Tel: 01-476 0935.

PAINSTAKING METHODS

Draw image by hand onto clear film or drafting film using dense black ink. Draw direct onto copper surface of PCB fibreglass, using etch-resist inking pen. Use etch resist PCB tracks and pads, taping direct to copper surface, or onto drafting film.

NEXT PRINT ONTO PCB

Place positive transparency onto photosensitised copper clad fibre glass,

cover with glass to ensure full contact. Expose to Ultraviolet light for several minutes (experiment to find correct time – depends on UV intensity).

Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

(PCB materials and chemicals are available from several sources – study advertisements.)

* CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.

ALTERNATIVE METHOD

Buy your PCB ready made through the PE PCB SERVICE, most are usually available – see page 60. ▪PE▪

DIGITAL POLY-WHATSIT!

BY JOHN BECKER

AN UNUSUAL EFFECTS UNIT

Following last month's ADA converter, the Polywhatsit is a dedicated controller which can produce conventional sound effects such as delay, echo and reverb, and also very unconventional ones, employing pitch shifting and reversal.

IN THE preceding article in May 1987, a general purpose audio analogue to digital to analogue converter (ADA) was described. This is suitable for use with a computer or a dedicated control unit for producing audio sound effects from sources such as musical instruments, high output microphones, and recordings.

The project to be described here shows an example of the type of dedicated controller that can be used with the ADA unit to produce the less conventional sound effects of pitch changing upwards and downwards with a range of over 3 octaves, and reverse tracking in which speech and musical phrases are played backwards. It also produces the more conventional effects such as echo, reverb and double tracking, with a time delay variable from 55ms to 440ms. Additionally, the conventional and unconventional functions can be combined to create effects that are grossly different to those normally published for audio units.

A-D-A AND CONTROLLER

In the ADA article it is shown that an audio signal can be repeatedly sampled, converted to a digital representation, sent out to a memory unit for processing, returned and converted back to analogue. Additionally, facilities for feed back and feed forward are included so that the type of effect that can be produced may be further varied by these controls in relation to the modification carried out at the memory control unit.

Basically the controller described here takes the digital signal from the ADA unit, stores it in a memory area of up to 8K bytes, and after a suitable delay returns it to the ADA. The way that the data is stored and retrieved is subject to several different parameters that determine the rate and direction in which the signal is read back. The block diagram in Fig. 1 shows the main functions.

DATA STORAGE

In Fig.2. the 8K byte memory chip, IC14, is used to store the data sent from the ADA. It has 65536 memory storage areas (64K), which are available in 8192 (8K) blocks of 8 bits (1 byte). Any byte can be accessed at any time depending upon a 13 bit address code sent to the memory. For normal writing of incoming data to IC14, on receipt of the DAVhigh level from IC2 of the ADA, the 12 bit ripple counter IC13 sends its address data to IC14 via the gates IC10 to IC12. The 13th address bit is derived from the flip flop IC16b which is triggered by each 12th pulse from IC13, and passed through the gate IC18.

With DAV high IC14 has its internal data output control inhibited by the high level on pin 22, and can accept the presence of the incoming data byte from ADA IC2. Approximately 4.5 microseconds later, a negative going pulse from ADA IC6 lasting for about 1 microsecond, triggers the memory to store (write) the incoming data byte at the relevantly addressed block. When the pulse ends, the memory goes into read mode, but with its outputs still inhibited. Shortly after the pulse has ended the DAV level falls to zero and the write address counter is stepped forward one place by the negative going edge. With DAV low the memory has its outputs enabled and the data stored at this new address becomes available to be read
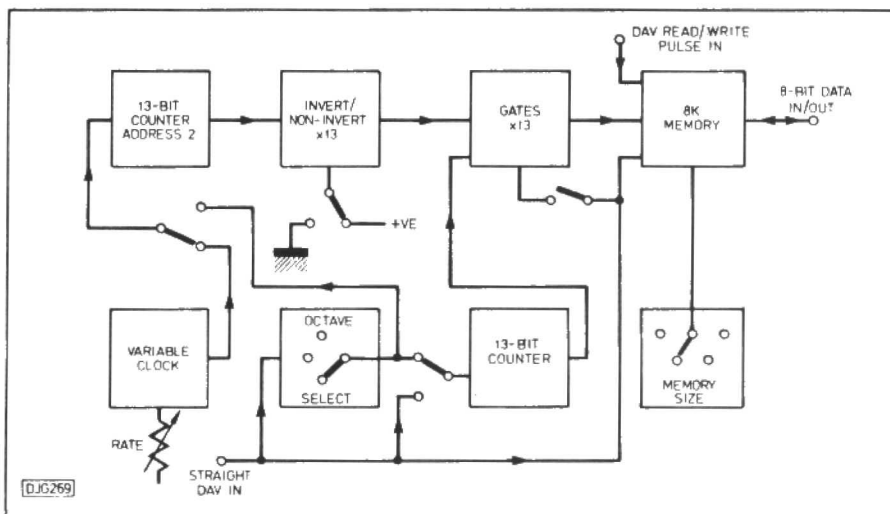
Fig.1. *Digital Poly-whatsit! Block diagram*
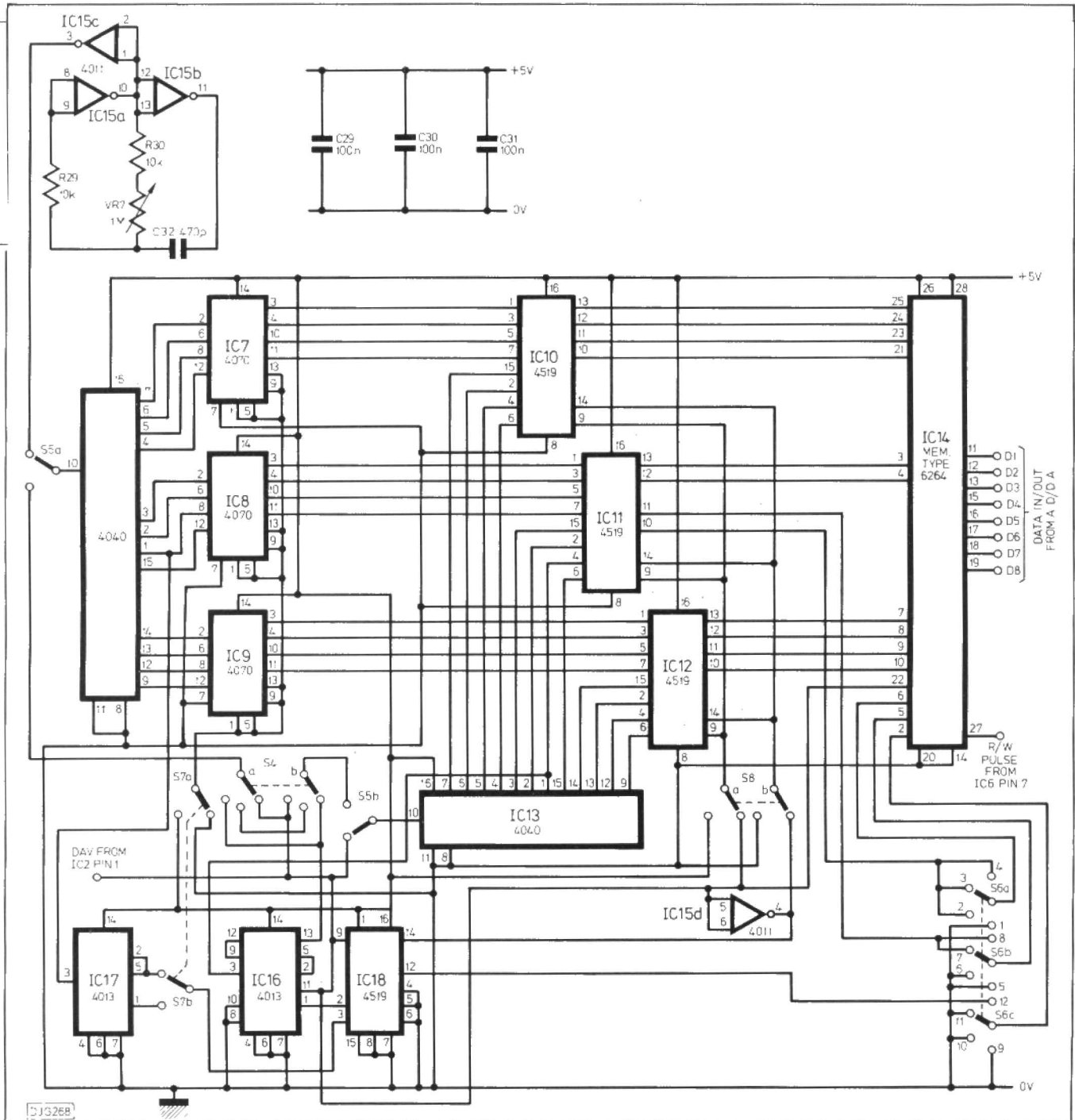
Fig.2. *Circuit diagram of Digital Poly-whatsit controller*

back by the ADA. Since this byte was recorded many cycles earlier, it is thus delayed in respect to its original storing, and is hence an echo signal. The echo delay depends upon the size of the memory, and the rate at which each byte is recorded.

READ BACK ADDRESS

The read back address can either be from IC13, as set by S8 controlling the gates IC10 to IC12 and IC18, or from the separately controlled address counter IC19 together with IC17, the latter being a flip flop triggered by the 12th bit to produce the 13th. This counter is normally clocking the address through at a different rate to IC13, depending

on whether the trigger comes via S4 or from the oscillator around IC15a-c. Whatever the trigger source, the 12 bits of IC19 go through the gates IC7 to IC9 and to the gates IC10 to IC12. The 13th bit goes direct to IC18 via S7b.

ADDRESSING GATES

The gates IC10-IC12 and IC18 are controlled by the voltage levels on their pins 9 and 14. These need to be of opposite polarity to each other for the gates to function as OR selectors. The selection is controlled by the DAV output from the ADA applied to pins 9, with an inversion performed by IC15a to control pins 14. When DAV is high, the gates are open only to IC13 and IC16b.

With DAV low, they are open only to the address lines from IC7 to IC9 and IC17. Switch S8 can remove this DAV control from the gates and replace it with fixed voltage levels so that the address is only derived from IC13 and IC16b. In this way the record and replay rates and displacement will be synchronised.

It will be of interest to digital enthusiasts that the address number arriving from the gates does not access the memory blocks of the same number. For example, the address counter sequence of 1 to 10 will actually access memory blocks 1, 512, 513, 64, 65, 576, 577, 1024, 1025, 1536 in that order. This is due to the address lines servicing the memory in an irregular order and does

DJG272

FREQUENCY
DOUBLING
PLAYBACK REVOLVES AT
TWICE RECORD RATE

FREQUENCY
HALVING
RECORD REVOLVES AT
TWICE PLAYBACK RATE

REVERSE
TRACKING
PLAYBACK IN OPPOSITE
ORDER OF RECORD
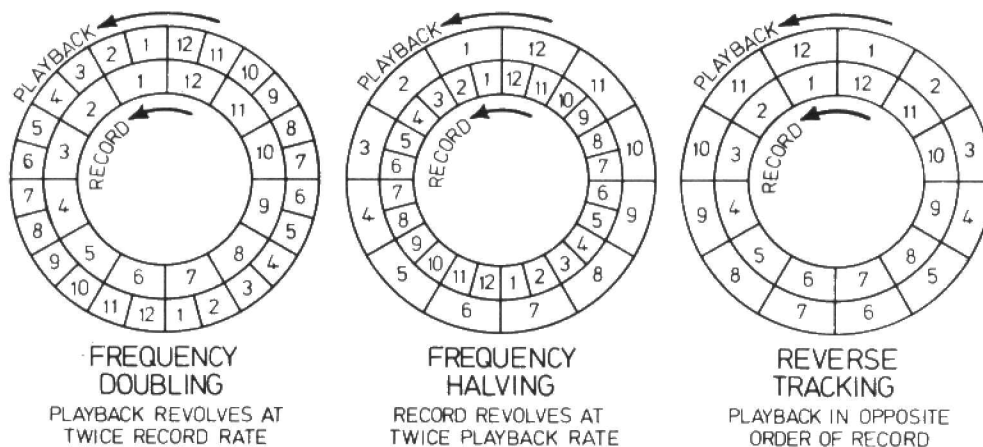
Fig.3. *Example of 12 byte block loop recorded and played back for different effects. Identical numbers refer to the same byte, whichever loop it is in.*

not alter the correct functioning since the order will always be consistent, irrespective of the direction of the count, as binary analysis will confirm.

INVERSION GATES

Normally the two counters are clocking upwards from 0 to 8191, resetting and starting over. Although they are probably counting at different rates the sequence of the count is always forwards. However if one counter goes upwards while the other goes downwards, signal data can be recorded in one direction, but replayed in the reverse order. Examination of a decimal to binary chart shows that this can be achieved by simply inverting the address bits, making logic 1 become logic 0, and vice versa.

Take for example, a 4 bit binary counter clocking through a sequence of decimal 0 to 3. This would normally count in order of binary 0000, 0001, 0010, 0011. If each bit is inverted the same sequence of decimal 0 to 3 becomes binary 1111, 1110, 1101, 1100. Converting these inverted binary numbers back to decimal it will be seen that the sequence has now become decimal 15, 14, 13, 12. The full sequence of decimal 0 to 15 when inverted would thus become decimal 15 to 0. The same holds true even for 10 bit binary numbers. Consequently if the output of one counter is inverted in respect to the other, data will be recorded forwards, but replayed backwards. If the amount of data available from the memory is sufficiently large, speech for example will sound as though it is being spoken backwards.

The polarity of the first 12 bits is determined at the Exclusive OR gates IC7 to IC9. With S7a in the grounded position the gates pass the data through uninverted. In the positive position, the data is automatically inverted. Polarity

of the 13th bit is controlled by S7b selecting between the inverting and non-inverting outputs of IC17.

DATA REPLAY RATES

When both counters are clocked at the same rate, the rates of record and playback will be the same, even though they may be displaced in time. If the clocking rate of the read back counter is different from the write counter, then obviously a different replay rate will result. Since frequency by definition is determined by the rate at which the waveform is produced, then any change to the rate will result in a frequency change. Increasing the rate will increase the frequency, and slowing the rate will lower it. If the replay rate is twice that of the record rate, then there will be a frequency shift of one octave upwards. Halving the replay rate will produce an output one octave lower. Units that perform this are usually referred to as 'Octavers' for obvious reasons.

Octaving is accomplished here by the switched insertion by S4 of a divide by two counter IC16a. The DAV input goes to IC16a where the output rate is half that of the input. With S4 in position one, the divided rate clocks the write address counter and the DAV rate clocks the read counter. Playback thus occurs at twice the rate of record. In position two, both counters are clocked at the same rate by the DAV, so record and playback rates are the same. In position three, the record address counter is clocked by DAV, but the read counter is clocked by the divided rate, so replay is at half the rate of record.

VARIABLE FREQUENCY SHIFT

Variable frequency changes upwards and downwards are available by the inclusion of the oscillator IC15a-c which

can be switched in to the read counter IC19 via S5a. S5b then ensures that IC13 is only clocked by DAV. The oscillator rate is basically set by C32 and variable by VR7. The replay rate is fully variable from a little lower than one octave down, to over two octaves upwards. Since the replay rates can be reversed as well as varied, some quite astonishing and indescribable effects can be obtained. In conjunction with signal feedback, producing reverb, further interesting sounds result, since each time the signal goes round the reverb loop its frequency is again shifted until the filter cut off level intercedes.

MEMORY CAPACITY

By now you are probably puzzled as to how live data can continually be recorded at one rate and replayed at another. Surely something must be lost somewhere? This is quite true, with a higher rate of replay than record, the replay will eventually run out of data, and with a lower rate a big time lag will develop. However this is solved by the fact that the data is recorded in a loop. As soon as an address counter reaches the maximum, at the next change it will revert to zero and go through the cycle again. Consequently for a faster replay, once there is no data to read at the end of a cycle, so the earlier data is reread as the read loop goes round again. With a slower replay rate there is a jump ahead in the data reading as the write loop catches up and overtakes, and some information is ignored. With careful selection of the length of the loop, that is, with the size of memory, so the effect of repeating or losing data can be minimised. (Fig.3.).

The effective memory size attributable to IC14 depends upon the upper address limit. Normally with all 13 address lines in operation, all 8K of memory can be

Fig.4. *PCB details*

P.C.B. PINS 101 TO 108 GO TO P.C.B.
PINS 1 TO 8 RESPECTIVELY

P.C.B. PIN 120 GOES TO
P.C.B. PIN 10

(P.C.B. PIN No's LESS
THAN 100 ARE ON
AUDIO P.C.B. 251A).
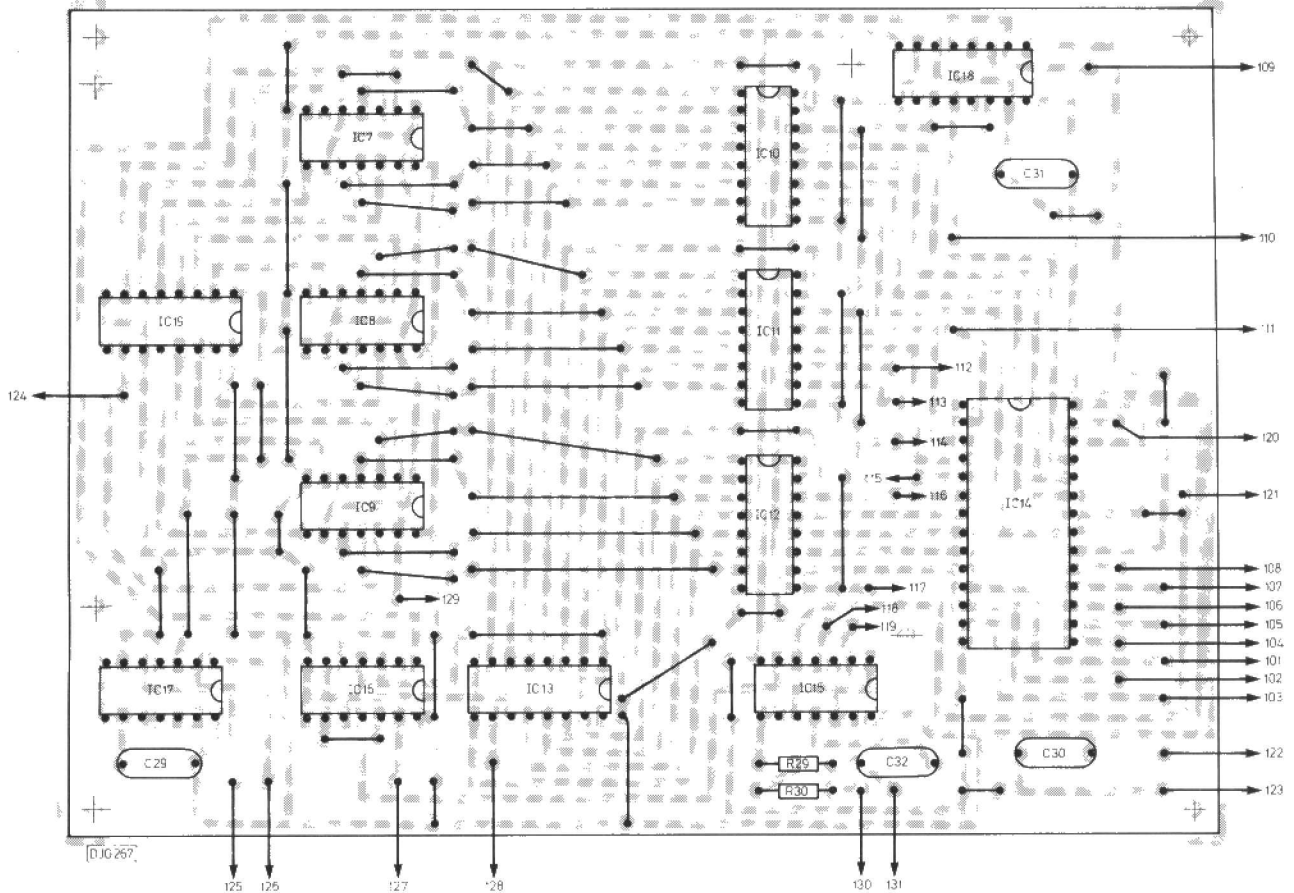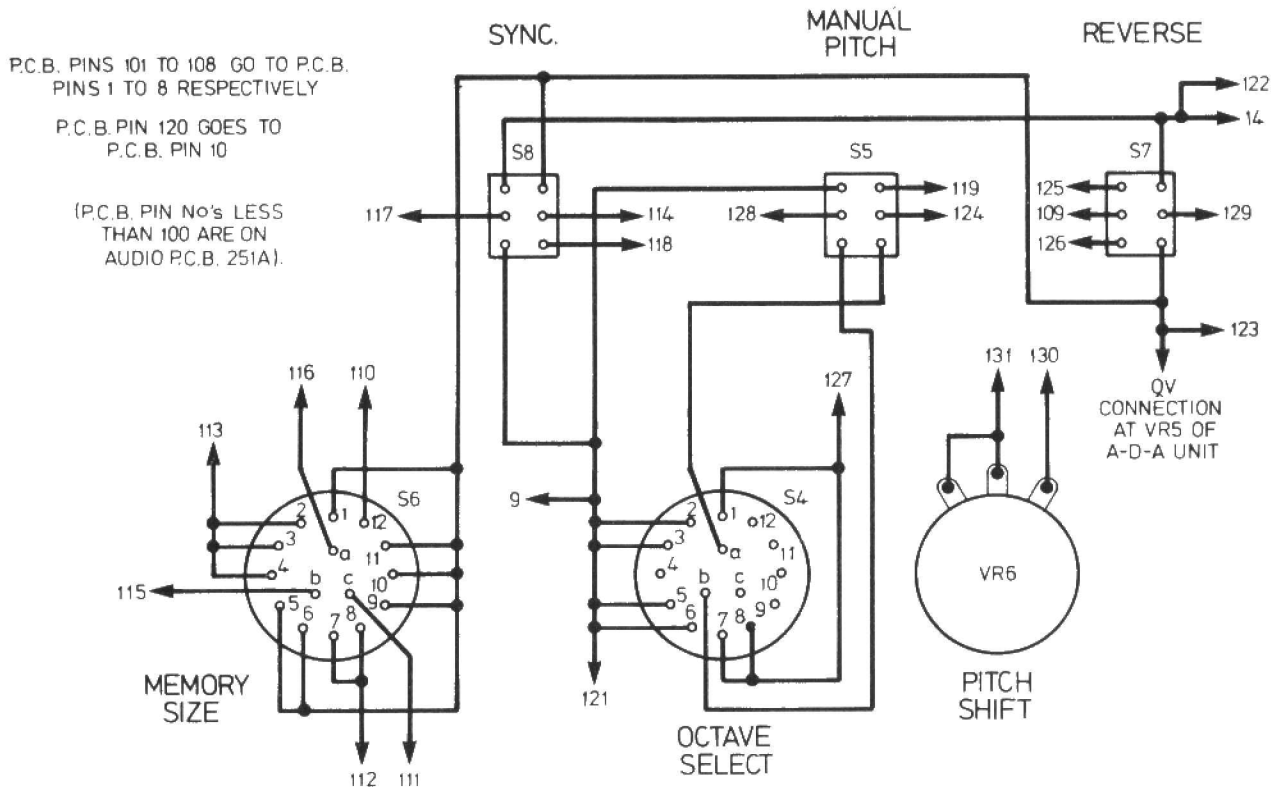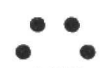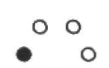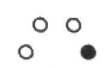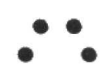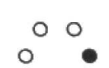
Fig.5. N.B. *Wiring to be used in conjunction with chart for PCB 251A (ADA PCB published last month).*

	FEEDBACK	OCTAVE	MEMORY SIZE	ORIG.	REVERSE	PITCH MANUAL	SYNC.
	VR5	S4	S6	S3	S7	S5	S8
NORMAL ECHO AND REVERB	YES	1 or 2	ANY	↓ ON	X INOP	X INOP	↓ ON
NORMAL DOUBLE TRACK	NO	1 or 2	ANY	↓ ON	X INOP	X INOP	↓ ON
FIXED OCTAVE HIGHER	NO	3	1	↑ OFF	↕ EITHER	↑ OFF	↑ OFF
FIXED OCTAVE LOWER	NO	1	4	↑ OFF	↕ EITHER	↑ OFF	↑ OFF
VARIABLE FREQUENCY	NO	X INOP	ANY	↑ OFF	↕ EITHER	↓ ON	↑ OFF
NORMAL REVERSE TRACK	NO	2	4	↑ OFF	↓ ON	↑ OFF	↑ OFF

DJG270

Fig.6. *Control modes. Any combination of controls may be selected to produce other effects.*

COMPONENTS . . .

RESISTORS
R29,R30   10K (2 off)
Both resistors ¼w 5% carbon film

CAPACITORS
C32   470p polystyrene
C29–C31   100n polyester (3 off)

POTENTIOMETER
VR6   1M mono rotary

SEMICONDUCTORS
IC7-IC9   4070 (3 off)
IC10-IC12,
IC18   4519 (4 off)
IC13,IC19   4040 (2 off)
IC14   6264
IC15   4011
IC16,IC17   4013 (2 off)

SWITCHES
S4,S6   3p-4w (2 off)
S5,S7,S8   min d.p.d.t. (3 off)

MISCELLANEOUS
Pcb clip tops (4 off), Stacking pcb clips (4 off), Knobs (3 off), PCB252A, 14-pin i.c. socket (6 off), 16-pin i.c. socket (6 off), 28-pin i.c. socket. Printed circuit board and kit of parts available from Phonosonics – see advert.

used. If the number is progressively decreased by inhibiting counter address lines, then fewer memory areas can be used. S6 can select which upper address lines are inhibited. If counter line 13 is inhibited, the usable memory size is halved to 4K. With 13 and 12 both inhibited it is 2K, and with line 11 out as well it becomes 1K. So, by selection of the memory size, the loop replay rate can be altered, the jump ahead displacement changed, and the delay
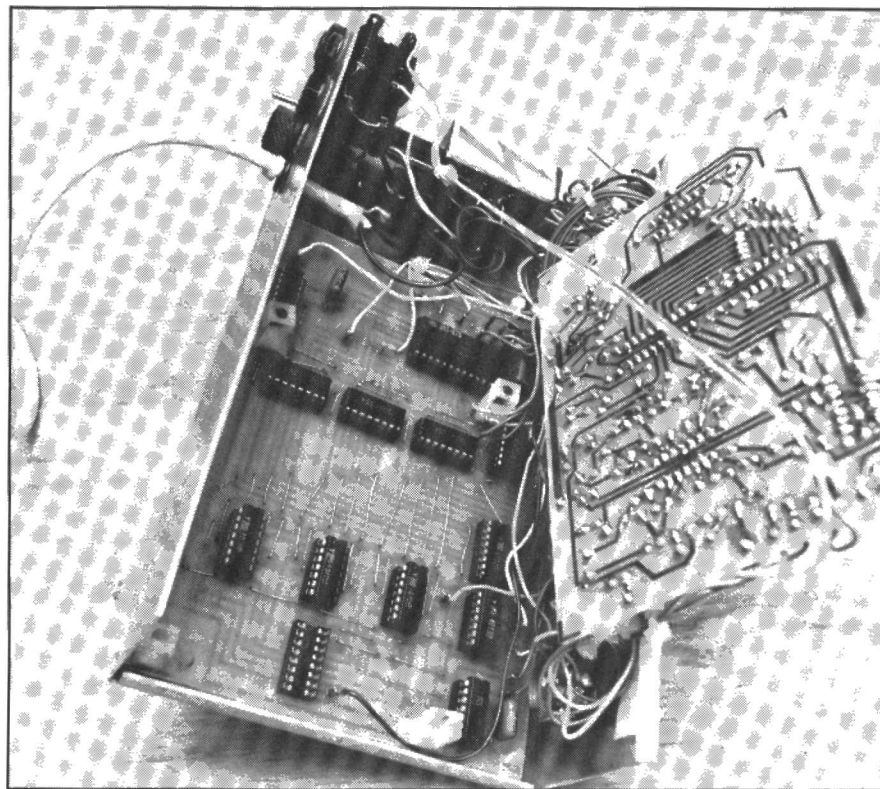
Interior of complete ADA Digial Poly-whatsit. The control board is at the bottom. The turned back board is the track side of the Audio ADA converter.

between record and read amended. These variations have a significant effect upon the nature of the sound produced.

It is inherent that with varying the replay rate of a live loop, that the result will not be the same as varying the rate of replay of a prerecorded signal on disc or tape where the information is in one continuous length. With a live record and playback system as is used in this unit, naturally there will be a join between the end and the start of the recording loop, and another join for the replay loop end and start. Unless the waveform frequency and the loop length and rate are synchronised, the sample bytes to either side of the loop join may be at different levels, and on a single frequency the waveform may hiccup at the join. On more complex waveforms though, such as speech or rapidly varying music frequencies, the join is usually less perceptible, though a tremolo type of effect will probably be heard, particularly with frequency changes upwards.

MODULE INTERCONNECTIONS

The interconnections between this digital controller and the ADA unit are shown in Fig.5. All the short link wires on the ADA PCB should be connected as shown in that article, and the optional computer control connections ignored. The unit here draws about 60mA and takes its 5v supply voltage from the ADA stabilised power supply. Setting up is confined to the two presets VR2 and VR3 of the ADA as discussed previously, no other adjustment is needed.

With the box as shown, measuring 23 × 13 × 6.3cm, the digital board is mounted to the far rear left hand side, with the ADA board mounted above it using the selectively displaced mounting holes. The box should be drilled for the rotary controls to be mounted with their centres 3cm up, 3.5cm apart, starting 2.5cm from the left. Toggle switches are mounted in line between the pots with centres 4.6cm up.

USE

Any combination of switches and controls can be used to create a remarkable variety of sound effects in conjunction with the type of sound original fed in. The chart Fig.6. shows some of the major effects settings. With the large number of switch and control settings available, an even wider variety of fascinating effects can be actually produced. These effects are so unusual and varied, that there really is no descriptive name for the unit other than Poly-Whatsit!

PE

INFRA-RED TRANSCEIVERS

BY THE PROF

INFRA-RED GOES TO THE HEAD

Cordless headphones can employ frequency modulated infra-red signals to transmit and receive near hi-fi quality audio. Ingenious deployment of photo diodes and l.e.d.s modifies the range and reception area of the signals.

IN a previous article in this series the subject of inductive loop transmission was considered, and the alternative of so-called 'cordless' infra-red headphones was mentioned. In this article we will take a detailed look at this interesting subject. Like inductive loop systems, the idea is to drive a pair of headphones without any direct connection from the signal source to the headphones. However, inductive loop systems are generally used where very high quality is not needed, whereas infra-red systems are aimed more towards hi-fi use. The quality that can be attained with even quite simple infra-red systems is higher than might be thought, and the main problem that has to be overcome with equipment of this type is obtaining a usable operating range, rather than obtaining low noise and distortion levels.

Another difficulty which has to be overcome is that of making the receiver unit small and light enough to be a practical proposition. There is little point in freeing oneself from a cumbersome connecting lead and replacing it with a heavy receiver unit which makes the headphones uncomfortable to wear. With this type of equipment it is normal for the receiver to be built onto the headphones, and it is usually placed on top of the headband where the infra-red detector will not be obscured from the transmitter by the user's head.

With most modern headphones this approach is bordering on the impossible since the headphones are of such light construction and have a type of headband which makes fixing the receiver in place very difficult. What is probably a more practical approach in most cases is to have the receiver unit connected to the headphones via a short lead, with the receiver then being positioned (say) on the arm of a chair. It is up to the constructor to choose whichever method best suits the individual circumstances, but in both cases the receiver needs to be as small and light as possible.

HEAD START

Cordless infra-red headphones invariably seem to be based on a frequency modulation (f.m.) system. The principle advantage of an f.m. system in this case is that it renders any non-linearity through the photocells irrelevant, and this is important as quite high levels of distortion could otherwise be introduced by these components. Of course, use of an f.m. system does not automatically give a high quality output, and in order to take advantage of this method it is essential that the modulator and demodulator both have good linearity. The block diagram of Fig.1 shows the arrangement used in my initial system.

distortion on the output signal. Some signal sources, particularly compact disc players and stereo f.m. tuners, tend to have a certain amount of output in the ultrasonic range.

The audio signal is fed to a voltage controlled oscillator (v.c.o.), and this has an output frequency which varies in sympathy with the applied control voltage. A type with good linearity is needed in this application, but these days there are several integrated circuits that enable a high quality v.c.o. to be produced without the need for undue complexity or expense.

A high current buffer stage is needed at the output because the infra-red l.e.d. must be driven at a fairly high current in order to obtain a reasonably strong
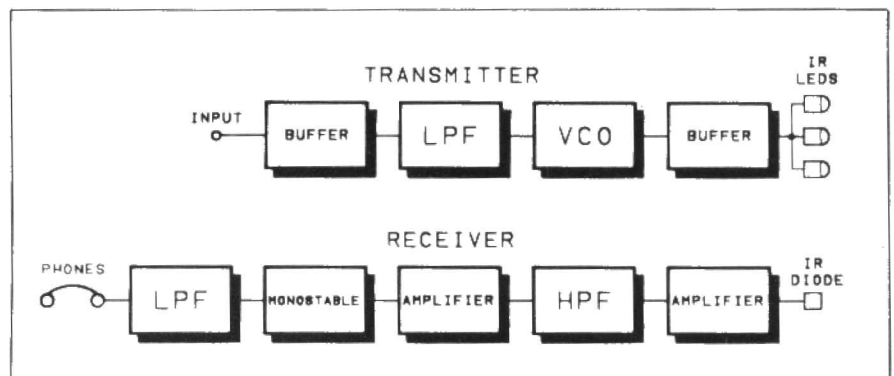
Fig.1. *Block diagram of cordless infra-red headphone system*

Starting with the transmitter side of things, a buffer stage and lowpass filter are used at the input. The buffer stage provides the unit with a reasonably high input impedance and provides a low output impedance that can drive the lowpass filter properly. The purpose of the lowpass filter is to remove input signals at frequencies close to the carrier frequency, which could otherwise cause unwanted heterodyne whistles and other noises on the final audio output signal. These frequencies are outside the audio range, but there is still a danger that the signal source will provide signals within the relevant frequency range. This could be caused by stray pick up of signals in the connecting cable, or due to

output signal. In fact a single l.e.d., even when driven at a current of one hundred milliamps or more, is unlikely to give usable results in practice. Ideally a bank of eight or more l.e.d.s are needed. Unfortunately, doubling the number of l.e.d.s in the bank does not double the range of the system. The infra-red signal spreads both vertically and horizontally, so that a doubling of range gives coverage over four times the area, but with only one quarter of the signal intensity. Using four times as many l.e.d.s in the bank therefore gives only a doubling of range. The practical consequence of this is that as the number of l.e.d.s in the bank is increased, the effect of each additional l.e.d. becomes

less. Thus, with eight l.e.d.s in the bank, to double the range of the unit a further twenty four would be needed, giving a total of thirty two.

The number of l.e.d.s used therefore has to be something of a compromise. About eight to ten l.e.d.s gives a useful increase in performance when compared to a single device and does not vastly increase the cost of the system. Further improving the performance by a worthwhile amount would require the use of what would probably be an impractical number of l.e.d.s, and would vastly increase costs.

A ploy which can be used to boost the performance of the system is to drive the l.e.d.s at a very high current, but to use a very short pulse width. For instance, with a 1:4 mark space ratio and a drive current of 250 milliamps the average l.e.d. current would be 50 milliamps. This gives strong pulses of infra-red but keeps the average l.e.d. current within an acceptable limit. In practice, this system is not quite as good as it would first appear. Using short pulses reduces the strength of the fundamental frequency and boosts the harmonics. The receiver therefore needs a wider bandwidth in order to prevent it from rounding off the pulses and reducing their peak amplitude. This wider bandwidth gives a higher noise level which tends to counteract the stronger transmitted signal. Nevertheless, the use of this pulsing technique seems to give some overall advantage, and it only requires the addition of a simple pulse shaping circuit of some kind between the v.c.o. and the buffer amplifier. This refinement has been included in the final version of the transmitter circuit.

The receiver uses a large area infra-red diode to detect the pulses from the transmitter. Although devices of this type offer a good compromise between sensitivity and bandwidth, the output level will normally be very low, at well under a millivolt peak to peak. A high degree of amplification must therefore be used to boost the signal to a level that can properly drive an f.m. demodulator. Highpass filtering is used in this part of the circuit in order to give a lower noise level, and lowpass filtering could also be used. However, as explained previously, with a narrow pulsed signal from the transmitter the receiver needs to have a wide bandwidth in order to give good results. There certainly seems to be no advantage in using additional components to give a faster roll-off than the natural high frequency roll-off of the amplifier, and no lowpass filtering has been included in the final design.

There are various types of demodulator that can be used in a low frequency f.m. application, including phased locked loop and quadrature detectors. What is probably the simplest
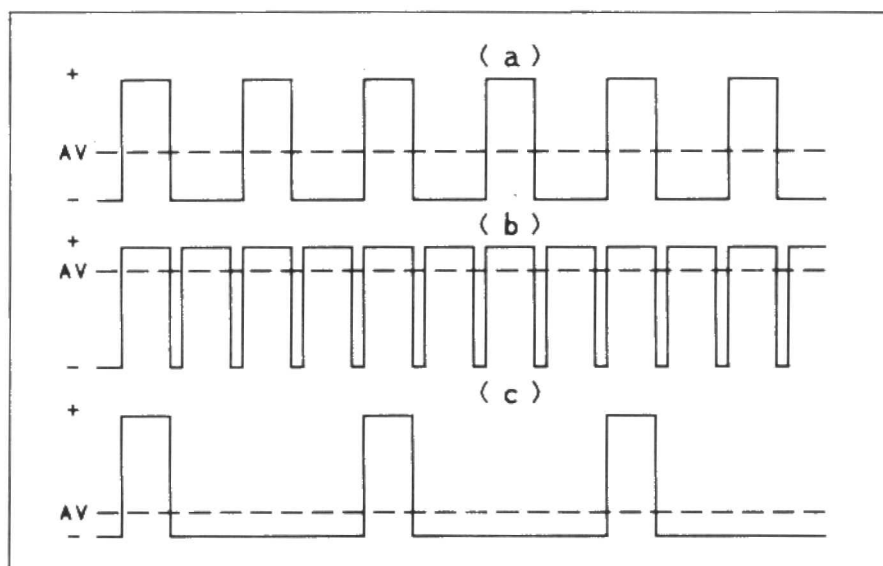
Fig.2. Monostable output waveforms

type, but one which offers excellent linearity, is an ordinary non-retriggerable monostable multivibrator plus a lowpass filter. This may seem like an unlikely form of demodulator, but it works no less well because of that. The waveforms of Fig.2 help to explain the way in which a monostable multivibrator can provide frequency to voltage conversion.

Taking Fig.2(a) first; this waveform has a 2:3 mark-space ratio, and the average output voltage is therefore 40% of the supply voltage. In Fig.2(b) the input frequency has been doubled and there are twice as many pulses in a given period of time, but the pulse duration is the same as before. This gives a mark-space ratio of 4:1, and the average output voltage is increased to 80% of the supply voltage. The input frequency in Fig.2(c) is only half that of our first example, and this spreads out the pulses to give a mark-space ratio of just 1:4, and an average output voltage of only 20% of the supply voltage.

It should be apparent from this that changes in the input frequency produce a corresponding change in the average output voltage. Furthermore, there is a linear relationship between the input frequency and the average output voltage. Apart from their simplicity, the excellent linearity over a wide input frequency range is the main attraction of this type of demodulator. Of course, the pulsed output waveform does not constitute a demodulated audio signal, but the lowpass filter has the effect of smoothing the pulses to give a proper audio output signal. In fact the pulses would probably give a quite acceptable audio output signal if fed direct to the headphones, as they would not respond to these high frequency pulses properly, and would provide a sort of mechanical lowpass filter which would integrate the pulses. In practice it is probably best to play safe and include reasonably effective lowpass filtering at the output of the

unit. Apart from anything else, this ensures that only an insignificant level of radio frequency interference is radiated from the headphones and the output lead.

TRANSMITTER CIRCUIT

The full circuit diagram of the transmitter unit appears in Fig.3. The input signal is fed to an operational amplifier voltage follower circuit based on IC1a, and this gives the unit an input impedance of about 50k. From here the signal is fed to the lowpass filter, and this is an active third order (18dB per octave) type which has IC1b as the buffer amplifier. The cutoff frequency is at approximately 20kHz, and consequently this filter does not prevent the unit from achieving the full audio bandwidth.

IC2 is a CMOS 4046BE micro-power phase locked loop, but in this circuit only its voltage controlled oscillator stage is used, and the other sections (such as the phase comparators) are ignored. The v.c.o. of the 4046BE is well suited to operation in low frequency f.m. systems as it has a wide frequency range with excellent linearity. The carrier frequency under quiescent conditions is about 70kHz, and is controlled by timing components R7 and C8.

IC3 is a 4001BE CMOS quad 2 input NOR gate, but here only two sections of the device are required and the other two simply have their inputs tied to earth to prevent spurious operations. The other two gates operate in a conventional CMOS monostable mode, and the output pulse duration can be adjusted by means of VR1. The l.e.d.s are driven via a VMOS power f.e.t. (TR1) which is suitably rapid in operation and can provide output currents of up to 2 amps. The infra-red l.e.d.s are driven in series connected pairs, with an individual current limiting resistor for each pair. In Fig.3 only two pairs of l.e.d.s are shown, but it is up to
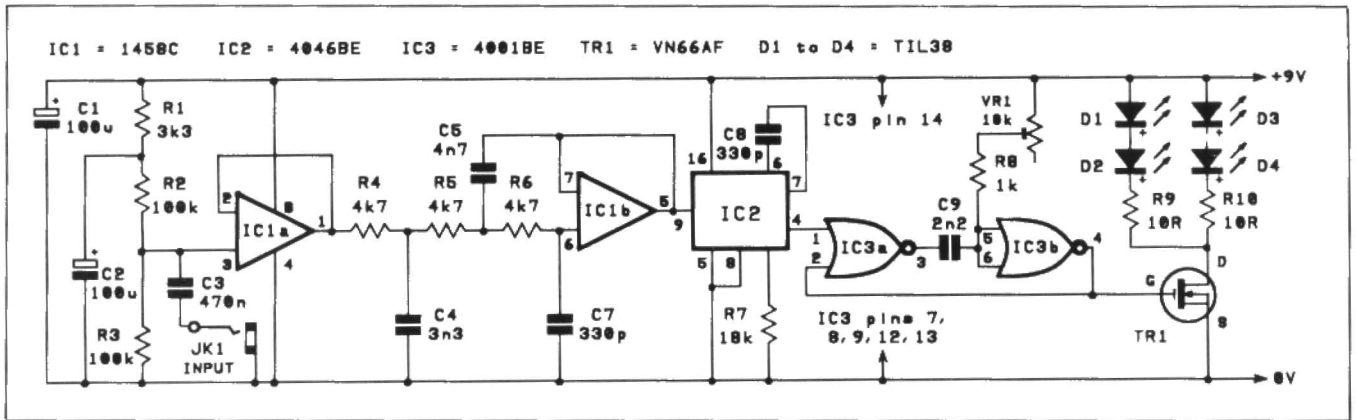
Fig.3. *The complete transmitter circuit diagram*

you as to how many are fitted to the unit. I used eight, and found that TR1 was capable of driving these satisfactorily. However, this is about the largest number that can be driven from a single VN66AF device, and if a greater number are to be driven, then one or more additional driver transistors will be needed. The monostable is well able to drive two or three VMOS transistors, and could in fact drive a dozen or more of these devices which have the high input impedances associated with field effect devices.

RECEIVER CIRCUIT

The circuit diagram of the receiver appears in Fig.4. D1 is the detector diode, and it is operated in the usual reverse bias mode. The pulses of infra-red cause D1's leakage level to increase, giving a sort of insensitive photo-resistor action. The TIL100 is a type which has a built-in infra-red filter. This helps to avoid problems with interference from the ambient light, and about the only likely source of infra-red interference is tungsten mains lighting. This is unlikely to give any 'hum' problems as the 100HZ signal is well below the signal frequency range and is severely attenuated by the highpass filtering. Also, a frequency modulation system has good immunity to sources of interference such as this.

A three stage amplifier is used, and this has three identical high gain common emitter stages with capacitive coupling. The coupling capacitors have

purposely been given quite low values so that they effectively form a three stage passive highpass filter in conjunction with the input impedances of the three amplifiers. The total voltage gain of the amplifiers is extremely high at well over 100dB, and the bandwidth is quite wide. This leaves the circuit open to problems with instability, although the fact that the input and output of the amplifier are out of phase helps to ease matters slightly. However, it is still necessary to take reasonable care with the component layout, especially if the circuit board is made as small as possible and the amplifier components are rather crammed together.

The monostable is a CMOS type that is essentially the same as the type used in the transmitter circuit. The lowpass filter is also basically the same as the one used in the transmitter, and again has a cutoff frequency of about 20kHz. The system thus achieves the full audio bandwidth, and is capable of high quality results in this respect.

IC2 is capable of driving most types of headphone satisfactorily. With most types series connection of the phones will give best results, but with high impedance (and possibly some medium impedance) types parallel connection must be used in order to give reasonable volume. With low impedance types it will probably be better if a resistor of about 47 ohms in value is connected in series with the output. This gives a certain amount of attenuation and gives a more

satisfactory load impedance for IC2. The unit will also drive a crystal earphone satisfactorily, but it is unsuitable for operation with low impedance magnetic types, or headphones that are designed to be driven direct from loudspeaker outputs.

IN USE

Before applying power to the transmitter, set VR1 at minimum resistance. Use a multimeter to monitor the supply current and adjust VR1 to bring the current up to 50 milliamps per pair of l.e.d.s (e.g. 200 milliamps with a bank of eight l.e.d.s). Note that if you use more than four l.e.d.s TR1 will need to be fitted with a small heatsink. The current consumption of the transmitter is obviously quite high which makes battery operation impractical unless a fairly high capacity NiCad rechargeable battery is used. A mains power supply would be a more practical proposition, and it must provide a reasonably well smoothed and stabilised 9 volt output. The unit can be driven from the headphone output of virtually any television set, hi-fi system, or whatever, and an input level of about 1 volt RMS is required. Some signal sources may not be able to supply a signal at quite this level, but will still probably provide enough output to give good results. However, if necessary the input stage could be revamped slightly so as to give a certain amount of voltage gain.

With a signal at a suitable level
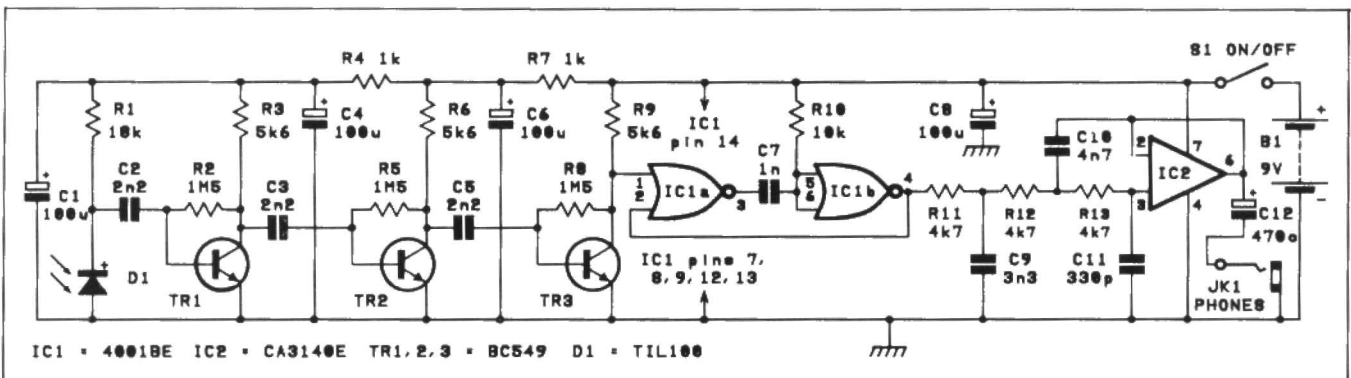
Fig.4. *The cordless headphone receiver circuit*

coupled to the transmitter, the output from the receiver should be of good quality with no obvious reduction in quality when compared with the signal source. This assumes that the infra-red detector diode is receiving a good signal, and an inadequate signal level will be apparent from a relatively poor signal to noise ratio. If the detector diode is placed too close to the transmitter there is a risk of the amplifier in the receiver being overloaded with a very distorted audio output being produced as a result. This is unlikely to happen in normal use where the transmitter to receiver distance is never likely to be short enough, but it can be avoided anyway simply by adding a 1N4148 silicon diode from the base of TR3 to the negative supply rail (the cathode connecting to TR3's base).

In use it is too little signal rather than too much which is likely to be the problem. I found that the system worked well at about 2 metres, but was starting to show signs of significant background noise at 3 metres, and all but ceased to work at 4 metres. This is quite usable in some circumstances, but would obviously be inadequate if the system was needed for operation in a large room with a fairly long distance between the transmitter and receiver.

IMPROVED RANGE

There is probably little scope for improving the range by making modifications to the transmitter, other than by adding more l.e.d.s. As already pointed out, it takes a lot of l.e.d.s and extra power to give a large improvement in range, but if only a marginal increase in performance is required this is an approach which would probably be worthwhile. Optical systems can give improved range, but these tend to make the system highly directional, which renders them useless in this application.

The receiver offers more scope for improvement, and one very simple way of obtaining improved performance is to add one or more photo-diodes in parallel with the existing one. This can improve performance in two ways. Firstly, if the diodes are all aimed in the same direction they will simply act as one large
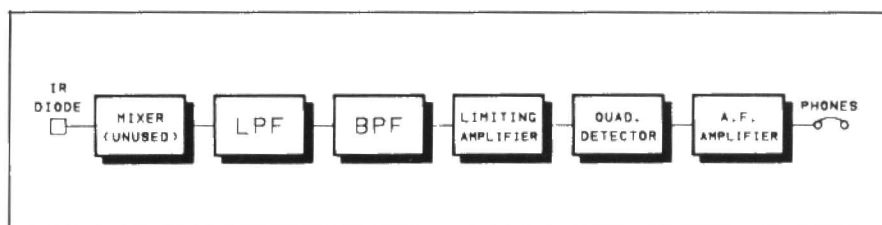
Fig.5. *Block diagram for the TDA 7000 headphone receiver*

diode, giving increased sensitivity. Secondly, if they are aimed in different directions they reduce the directivity of the system, and avoid having the signal disappear if you turn your head away from the transmitter. Two pairs of diodes facing in opposite directions seems to offer very good performance.

There is plenty of room for experiment with different types of receiver circuit. I tried one based on the TDA7000 f.m. radio integrated circuit, which is an unusual device that operates with an intermediate frequency of only about 70kHz and uses C–R intermediate stage filtering. There is insufficient space available here for a full description of this device, but when used in this application it provides the stages shown in the block diagram of Fig.5 (apart from the audio output stage which is provided by a separate device).

The mixer is unused in this case, but it is included in the signal chain as the only route into the i.f. stages is through this stage. The i.f. stages consist of a lowpass filter, a bandpass filter, and then a high gain limiting amplifier. The demodulator is a quadrature type, but it does not require a tuning inductor. In fact the only discrete component it uses is a capacitor which forms part of the phase shift network. The audio output level from the detector is quite low, and the audio amplifier has to furnish about 26dB of gain in order to give sufficient output to drive a pair of headphones.

The full circuit diagram of the TDA7000 version of the cordless headphone receiver appears in Fig.6. Most of the circuit consists of the TDA7000 itself and the numerous filter, phase shift, and decoupling capacitors that are needed in order to make it operate properly. The photo-diode (or diodes)

are coupled to the TDA7000 by way of an emitter follower buffer stage based on TR1. This is needed due to the low input impedance of IC1 which otherwise loads the diode very heavily, giving very little output signal even when a strong infra-red signal is received. At the output side IC2 acts as the audio amplifier and this is a simple inverting mode circuit.

The original transmitter circuit seems to operate well with this receiver circuit. About the only worthwhile modification to the transmitter is to replace R7 with a 10k fixed resistor and a 22k potentiometer in series, so that the output frequency can be optimised.

In use this receiver seems to provide better range and is less likely to cut-off if the photo-diode is not aimed in the general direction of the receiver. In terms of audio quality it does not quite seem to match the original circuit, and it is perhaps better suited to use where very high quality is not needed.

FURTHER DEVELOPMENT

Using these circuits with about eight l.e.d.s at the transmitter and several diodes at the receiver it is certainly possible to produce a practical cordless headphone system. I prefer the receiver with the monostable detector, as although this gives somewhat less range, it is still adequate in this respect for most purposes, and it has a noticeably higher audio output quality. A useful improvement would be a squelch circuit to cut off the audio output if the received signal should drop to an inadequate level.

The most obvious shortcoming of the system is that it is only monophonic. However stereo simulation just happens to be the topic covered in the next 'Experimental Electronics' article. **PE**
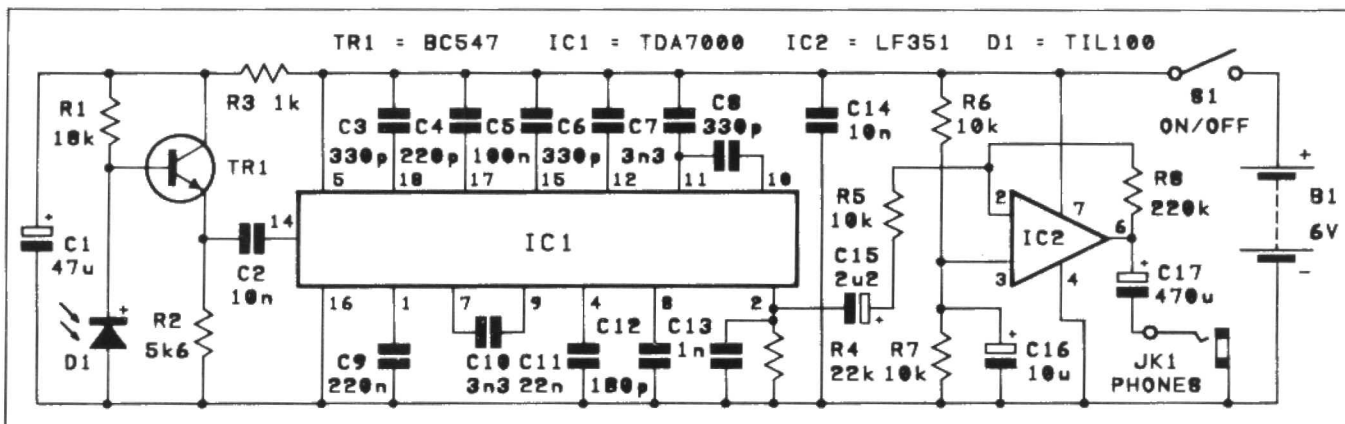
Fig.6. *Circuit diagram for the TDA 7000 receiver*

SPACEWATCH

BY DR PATRICK MOORE, OBE

The supernova in the Large Magellanic Cloud is the biggest astronomical event directly observed since 1604 – but we won't see it in the Northern Hemisphere.

THE great new William Herschel telescope, at La Palma in the Canary Islands, is now near completion, and work has already started with the James Clark Maxwell telescope on Mauna Kea in Hawaii, which operates in the microwave region of the electromagnetic spectrum. Other new telescopes are on the way – though we must, sadly, record that there is still no news of a rescue operation for the mothballed 100-inch Hooker reflector on Mount Wilson, which was so long the most powerful telescope in the world, and which was responsible for fundamental advances. Also, it seems definite that our own Royal Greenwich Observatory is to lose its headquarters at Herstmonceux Castle, and will be transfered to Cambridge, where it will inevitably play a comparatively minor role.

An interesting theory has been proposed to explain why Sirius, the brightest star in the sky, was classed as red in ancient times by many astronomers, including Ptolemy of Alexandria. Sirius is certainly not red today – it is a white Main Sequence star of spectral type A – and it is not the kind of star which would be expected to change over a short period of a few thousands of years. It has, however, a dim White Dwarf companion. Before reaching the White Dwarf stage, a star must become a Red Giant; and it has been suggested before now that Sirius B used to be a Red Giant in Ptolemy's time.

In America, F. Bruhweiler, Y. Kondo and E. Sion have now suggested that Sirius B went through a 'temporary red giant' phase, when the outer atmosphere of the star expanded and cooled because of a short-lived outburst. This would certainly explain the ancient redness of Sirius, but it looks as though a combination of a temporary red giant and the present Sirius would produce a star of outstanding brilliance – of which there is no mention in the old records. On the whole the theory seems unlikely, and it is more probable that we are dealing with a mistake in either observation or interpretation. Still, it is decidedly interesting.

THE SUPERNOVA IN THE LARGE CLOUD OF MAGELLAN

The first part of 1987 has been dominated by the news of a supernova in the Large Magellanic Cloud. It was discovered in February, and attained naked-eye visibility. It is therefore the brightest supernova seen since Kepler's Star of 1604.

Supernovæ are the greatest outbursts known to us. They are of two types. In the first of these we have to consider a binary system, one member of which is a White Dwarf. The White Dwarf pulls material away from its larger but less dense companion, finally becoming unstable and literally blowing itself to pieces in a cataclysmic outburst. With a Type II supernova, a very massive star 'runs out of fuel' and collapses; there is an implosion, followed by a shock-wave, and most of the material is blown off, leaving a remnant in the form of a very small, super-dense neutron star. Preliminary investigations showed that the Cloud supernova was of Type II. Moreover, instruments at the Mont

The Sky This Month

MAY 1987 is not a particularly good month from the point of view of the planetary observer. Venus, Jupiter and Saturn are all morning objects, but none is ideally placed even though all are bright – Venus and Jupiter particularly so. Saturn, with a magnitude of 0.1, remains in the constellation of Ophiuchus, which is not officially a member of the Zodiac but does cross the Zodiacal region between Scorpius and Sagittarius.

Mars remains on view during the early evening, moving from Taurus into Gemini, but it will be almost lost in the twilight before the end of May, and its magnitude is only 1.7 – not a great deal brighter than the Pole Star. Mercury passes through superior conjunction on May 7, but may just be glimpsed low in the west after sunset during the last days of the month.

The Moon is full on the 13th, and new on the 27th. There are no eclipses this month, and the only important meteor shower is that of the Eta Aquarids, which reaches its peak on May 5. This shower is associated with Halley's Comet, but there is no reason to expect any spectacular display this year – and Halley's Comet has now passed beyond the ken of all but giant instruments, not to return for more than seventy years.

We have lost Orion and the other brilliant winter stars, though Procyon and the Twins can still be seen for a while after sunset. The Great Bear or Plough is nearly overhead, and Leo, the Lion, is prominent in the high south; look for the curved Sickle, with the first-magnitude star Regulus. Follow round the Bear's 'tail', and you will come first to the brilliant orange Arcturus and then to Spica, in Virgo. Arcturus, with a magnitude of –0.04, is actually the brightest star in the northern hemisphere of the sky; its only superiors – Sirius, Canopus, and Alpha Centauri – are all south of the celestial equator, and the latter two are never visible from Britain. Next in order come Vega, Capella and Rigel, all of which are fractionally below zero magnitude.

The low south of the sky is occupied by the vast, sprawling and frankly dull Hydra, the Watersnake, and in the south-east are some more large but dim groups: Hercules, Ophiuchus and Serpens. However, well before dawn the red supergiant Antares, in the Scorpion, has risen in the south-east. It is unfortunate that Scorpius is always inconveniently low down as seen from Britain; at its best, as seen from southern countries, it rivals Orion in splendour.

Blanc neutrino observatory recorded a 'neutrino burst' which seems to have indicated the collapse of the star's iron core.

Fortunately the pre-supernova star can be identified; it was a B-type blue supergiant, around 25 times as massive as the Sun and therefore a stellar heavyweight. Its magnitude was around 13, and the identification seems certain, so that for the first time we have definite information about the pre-outburst stage. To be visible with the naked eye over such a distance, the peak luminosity must have been tremendous: perhaps 15,000,000 times that of the Sun. The

distance of the Large Cloud, and hence of the supernova, is usually given as about 180,000 light-years, though astronomers at the Royal Greenwich Observatory prefer the lower value of about 155,000 light-years.

It is unfortunate that once again northern observers are deprived of the chance to make observations. The declination of the supernova is −69 degrees, so that to see it at all adequately one must go south of latitude 15 degrees north – even Hawaii will not do, and we must depend upon results from observatories in Australia, South Africa, New Zealand and South America; the

original discovery was made at the Las Campanas observatory in Chile.

At the time when I write these words (March 4, 1987) it is still too early to say how the supernova will behave, or how bright it will become; but it is undoubtedly one of the most important astronomical events for many years. Astrophysics have been more than anxious to study a relatively nearby supernova with modern-type equipment. They would dearly like one in our own Galaxy; but if this is impossible, then an outburst in the Large Cloud of Magellan is the next best thing! PE

PE BAZAAR

Can anyone advise where I can obtain 0.0005 – 10KWV capacitors. I have tried without success. A. Slade, High Hopes, Letton Close, Blandford, Dorset DT11 7SS.

Modular Technology Minimodem with cables. Reasonable offers. Tel: 061 723 5037.

Enthusiast Retiring. 10kg Parcel, 500 brand new components plus other goodies. £14.75 post free (5 only). K. Bailey, 40 Seymour Close, Selly Park, Birmingham B29 7JD.

Wanted: Any information on MAEL 4000 computer and Log Abax LX180 printer. Justin House, Church View, Atherington, Umberleigh, N. Devon EX37 9HY. Tel: 0271 79073 before 5 pm.

Avomneter D.V.M. Never used £55. P. Evans, 46 Station Road, Weston-Super-Mare, Avon. Tel: ?934 31931.

Power supply, Eagle RP230N 0–309v, twin meters, variable current limiting, VGC !65.00. Phone: 01-654 1882.

Wireless world, Vol. 29 July to Dec. 1931. Bound, good condition for years. Offers (0865) 779855.

Points Arising

Switch Mode PSU Design (April 87). Pages 28,29. The diagrams for Figs. 5 and 7 should be transposed, Pages 35,37, Fig.2 and 7 should be transposed.

CORRECTIONS ADDED TO APRIL ISSUE

PRINTING PE

RUN AT 220 METRES PER MINUTE, COOKED AT 160°C

BY JOHN BECKER

Electronics and computerisation has infiltrated the print industry in a multitude of ways. Practical Electronics is one of the many beneficiaries – your editor has been along to see what PE's printers are up to, and found a warm welcome.

At the end of February I drove out to Andover to watch McCorquodales print the April edition of PE, and for personal interest, to see how electronics is being used in modern printing.

Each month, about ten days or so prior to a new PE issue appearing on bookstalls, the fully edited text and illustrational material is compiled by our typesetters and photographic masters produced, each holding eight pages of PE, four across and two down. There can be up to four masters for each block of eight pages, one each for yellow, blue, red and black, produced by laser scanning the original through special colour filters. Known as separation masters, they are transparent and hold a positive monochrome image of the original, in the form of minute dots varying in size according to image density. Ingeniously, the dots are at different angles, depending on the colour to be printed. When combined at the printing stages, they recreate the original full colour image. Text areas are faithfully reproduced as hard images without dots.

PLATE MAKING

From these masters, the printers make a metal printing plate, in a fashion similar to one method of making PCBs. The plates are basically anodised aluminium sheets that have have been coated with a photosensitive emulsion. The transparency is placed into contact with the sensitised surface, and enclosed in a vacuum press to ensure total contact across the entire surface area. It is then exposed to ultraviolet light for a few minutes, with electronic sensors measuring mains voltage, UV colour temperature and intensity, and controlling the exposure time so that a consistent overall exposure value is always achieved, irrespective of any fluctuation in conditions.

The plates are next fed through a chemical solution, which in effect develops and washes away the emulsion that has received direct exposure from the UV light, revealing the bare anodised aluminium surface. The dot image areas though, retain the emulsion, and it is to this surface that the printing ink will eventually be transferred. The processed image is then heat hardened in an oven electronically regulated at 270°C. The
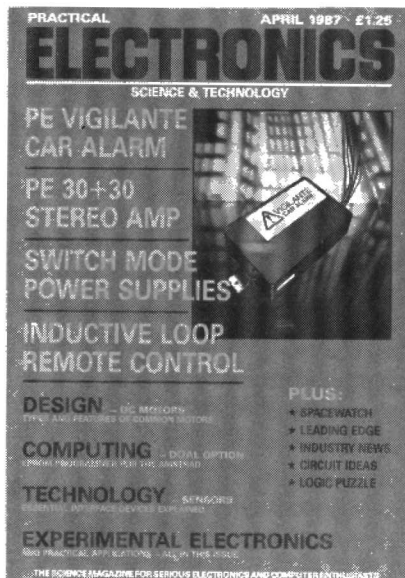

toughened image is strong enough to allow over 500,000 prints to be made from one plate.

Once the plates have been made, they are analysed by electronic densitometers that assess the image densities across the entire area. On the plate sizes used for PE, 24 separate evenly spaced areas are measured, and the levels sensed are digitised and stored in a computer data bank. This information will ultimately be used to control the amount of ink applied through 24 nozzles equivalently spaced on the press. Finally, the plate is shaped at the ends, and secured to the printing rollers by means of precision cut registration holes and pins.

THE PRESSES

McCorquodales have three printing presses on line, each in operation 24 hours a day for five days a week. All are recently installed, and between them
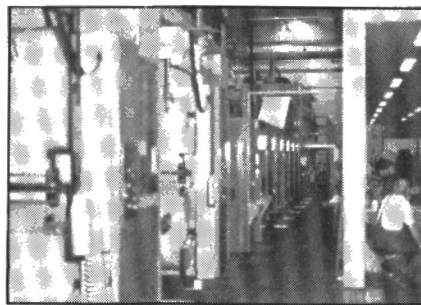
print over forty different magazines, ranging from PE, Office At Home and Astronomy Now, to Amateur Gardening and Tit-Bits. The three machines have their own individual computers, keyboard terminals, and control consoles.

Each of the presses is in fact six different printing machines coupled in series, any number of which can be brought into operation simultaneously, depending on the job, and between them can handle up to three reels of paper. Each of the machines prints simultaneously onto both sides of the paper, or web as it is known, so handling the equivalent of 16 pages of PE at the same time. The first three in the series are just for black ink, and the next three are for the red, blue and yellow inks.
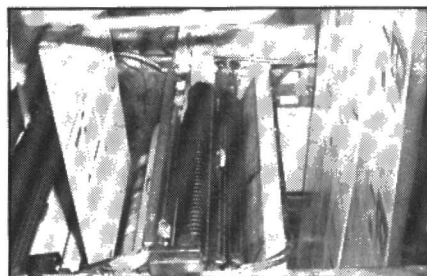
Water is sprayed onto the printing plates as they rotate. Because the aluminium is anodised, and so slightly porous, the water soaks into the pores preventing ink from being attracted. The greasy emulsion covered areas though, repel the water but readily attract ink as the plate passes the automatic dispeners. As the plate continues to rotate, the acquired ink is transferred to a synchronously rotating rubber roller, and then to the surface of the paper web as it passes.

When seeing the April PE going through, it was the three black ink units in operation first of all, between them printing 48 of the inner pages. When the required number of copies had been printed, the first two machines were disengaged. Following a period of cleaning down, fresh plates were then attached to the third black ink printer, and to the three colour printers. After this, the equipment was run again, printing the outer sixteen pages.

The printing speed is quite impressive, handling about 220 metres per minute on each machine, the equivalent of around 350 copies per minute. The total amount of paper used for editions of PE though, far exceeds the length of a single reel of paper. These measure 10,000 metres each, weigh over 750 kilos, and several are needed. Consequently, as one reel runs out, another must immediately take its place without interrupting the printing process. The change-overs are rapid, but interesting to watch.

Each huge paper dispensing stand holds two reels, either of which can be used. The paper is taken from one reel through a multiple series of pulleyed rollers that automatically control paper tension. Normally the rollers are close to full separation, but as the current paper reel nears its end, electronic sensors come into play, and at the relevant moment, the rollers close their spacing, letting the leading end of the paper continue at full speed, but enabling the trailing end to slow, and allowing the new reel to secure itself to the trailing end. Immediately following acquisition of the new reel, the rollers increase their separation again, bringing the reel up to correct rotational speed.

EXPERT SUPERVISION

All the machines have automatic control of their inking densities and precision alignment, though all operations are additionally under constant manual supervision. The computer sets the initial system control parameters, then the several operators use their expertise and experience to carry out the fine tuning, with the computer then maintaining control under any new parameters set manually.

Throughout the entire operation, copies are randomly extracted from the delivery end of the press, and examined in considerable detail, frequently with a magnifying glass, and various adjustments made to ensure the optimum print quality. To assist the detailed study, the extracted copies are placed on an examination easle underneath a bank of lights arranged like an audio parametric equaliser display. Horizontally there are 32 lights, though only 24 were in use as dictated by the sheet size, and 11 vertically, relating to percentage ink densities from nil to 100%. These lights correspond to the areas previously analysed
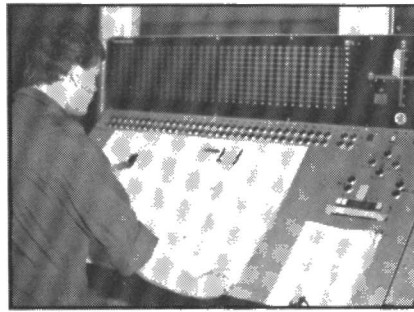
by the densitometer, and stored by the computer. Manual push buttons can increase or decrease the inking density factors, and the lights show a bar graph profile of the factors for each area. Any change made is immediately acted upon by the computer, which also stores the new data, so that should a repeat run be needed, the stored parameters can be recalled, and identical print qualities achieved.

REGISTERED APPROVAL

In addition to the inking levels, the registration accuracy of the separate images from each printing plate is under constant observation. Again the computer maintains very close control of positional parameters, using light sensors to detect specific registration marks on the plates. The operators though can modify the alignment by making panel controlled adjustments to the roller positions. These can be moved in three directions, horizontally across the page, lengthways for advancing or retarding the registration, or diagonally to compensate for any slight rotational misalignment of the plate.
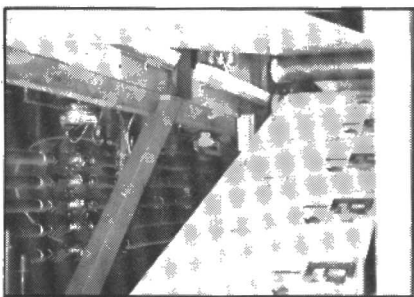
Opto-electronic devices are also much in evidence sensing for paper tears or breakage, and in the unusual event of these occurring, initiate the smooth shut down of all rollers simultaneously, preventing paper jams and spillage. I once saw the latter happen in an old paper mill – the scene of high speed spillage

was most dramatic, and it took an hour or more to sort out the mess!

During the printing process, as well as using computer aided inking and alignment control, an additional computer program is also running and displaying data on a VDU screen at the main control console. Numerous data factors can be called up, including the amount of paper required, the amount used, and the amount remaining on each reel. The printing rate is also displayed, together with the number of good copies so far printed, the reject level obtained during precision setting up, the time taken so far, the time scheduled, the remaining time available, and the percentage of the time budgeted. Access to the data files for other printing jobs, past or future, or pertaining to other printing lines, can also be called up.

Between them, the installation of the three complete printing lines cost around seven million pounds, and with a schedule involving over 40 titles, all of which have to be on newsagent's counters by specific dates, it is vital that all factors have to be under constant surveillance, ensuring that printing charges are both competitive and profitable.
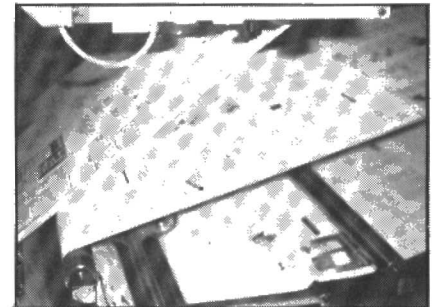
HOT OFF THE PRESS

Each of the three levels of paper leave the relevant printing machine and are routed, one above the other, into a vast gas fired drying oven. Thermal sensors and servo controls maintain the oven at 160°C, at which temperature the ink solvents evaporate and are burnt off. From the oven, the web passes over a bank of chrome cylinders internally cooled by flowing water. Thermostatically held at 15°C, the rollers shock-chill the paper web to set the ink pigment, and also restore the paper to a manageable temperature at which it can be folded without cracking through brittleness. With rate and tension still electronically controlled, the printed paper speeds out with the ink fully dry.
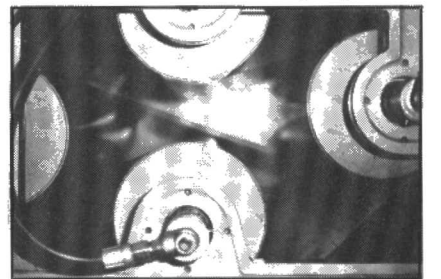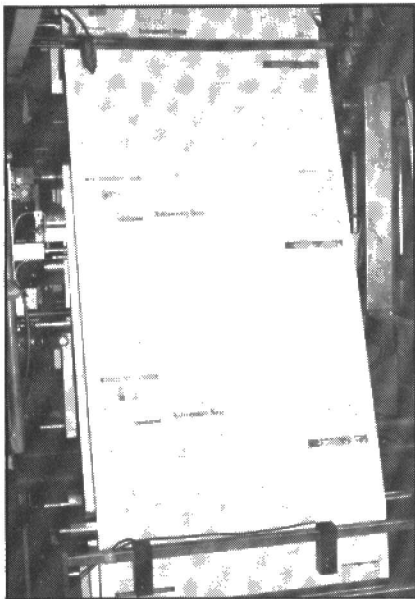
Now a clever series of rollers at 45 degrees to each other can take one length of paper and change its vertical position in respect to the others. This enables paper from the colour printers to be placed in a different makeup position, according to publishing requirements.
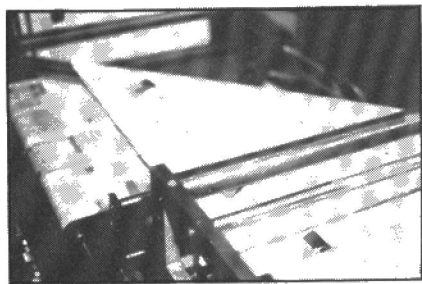
Following this, all three paper levels are brought together and routed into the first section of the folding machine. Here the impression is that of seeing the paper disappear down a vast funnel, but in fact this is an illusion and it is actually routed across and down another series of angled

rollers. These cause a lengthways fold down the centre of the triple thickness, bringing the two sides together to now give a six sheet thickness. Immediately after this, two more folds are made, and a rotational guillotine slices the paper into magazine sized sections. With three reels of paper in use, this results in a 48 page section coming off the machine, along a conveyor, past the quality control supervisors, and to an automatic stacking machine.

At this point, the sides of the folded sections remain uncut, so the supervisors, taking frequent samples, can unfold them for examination alongside the bar graph profile and control displays, and make any necessary adjustments.
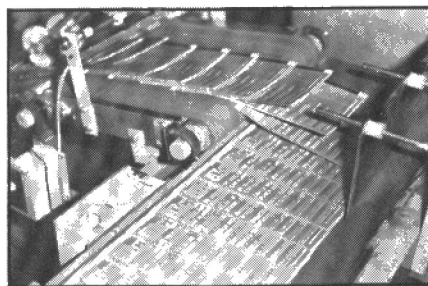
COMPLETION

The stacked sections go through to an enormous room in which the remaining stages are carried out. Electronic control is less evident here, and the equipment appears to be extremely fast conveyorised lines in which the various folded sections are combined and stitched with wire staples. Simultaneously, additional automatic equipment can enclose extra sections, such as promotional inserts etc. Following the stitchers, automatic machines guillotine-trim and stack the completed magazines into bundles of 50, turning the stack through 180 degrees every tenth copy, to keep the thickness even.

From there, bundles are wrapped in heavy duty polythene and strapped by more automatic equipment. The magazines are then ready for distribution to the trade and retail outlets by the specified day, on time for all eager readers to obtain their copies of the latest PE.

Throughout the full process, I was particularly impressed by several aspects. Firstly, that McCorquodales place strong emphasis on making visitors feel most welcome. Then, that a similar emphasis is placed upon minimising noise levels, and providing clean, spacious, and efficiently run premises, for the benefit of staff and customers. Thirdly, that electronics in many forms, both analogue and digital, from opto-sensors to complex computer controlled operations, is much in evidence. And finally, that everyone there takes great pride in ensuring that the magazine copy you receive is of the highest quality, for clarity of text, accuracy of colour rendition, and registration of four separate images.

We at PE work hard to offer you quality in projects and articles, and it is good to see at first hand that others in the production chain take as much care and interest in their work as we do. You really receive excellent value for the cover price of your favourite magazine.

PE

ZX SPECTRUM I/O PORT

BY P.B. SMALL

One output-only port, and one for true I/O, on one piece of strip board.

THIS piece of hardware will add two ports to the Spectrum, mapped as 191 for OUTPUT only, and port 255 which can be used for both INPUT and OUT-PUT operations.

IC2 acts as a decoder for seven of the lower address lines. When address lines 0 to 5 and 7 are high and the IORQ line is low, then the output from IC2 will be low. Dependant upon the state of address line 6, either IC4 or IC5 will be selected. If address line 6 is low (ie. OUT 191,n) IC4 is selected, whereupon the data on the data bus is latched onto the output, the latching signal being provided by the inversion of IC4's select line connected to IC6. If address line 6 is

high (ie. IN 255 or OUT 255,n) IC5 is enabled, and if a read operation is taking place then the RD line is consequently low and data is read from the 'outside world'. When this line is high then data is sent to the buffer IC5. However, if you do use this port for output, it should be noted that the data is not latched as with port A.

Construction of this project was effected by the author on a piece of VQ strip board about 80 x 80mm. When constructing the board it is important to note that ceramic disc capacitors C1 to C4 should be placed close to the i.c.s as per the circuit diagram. **PE**
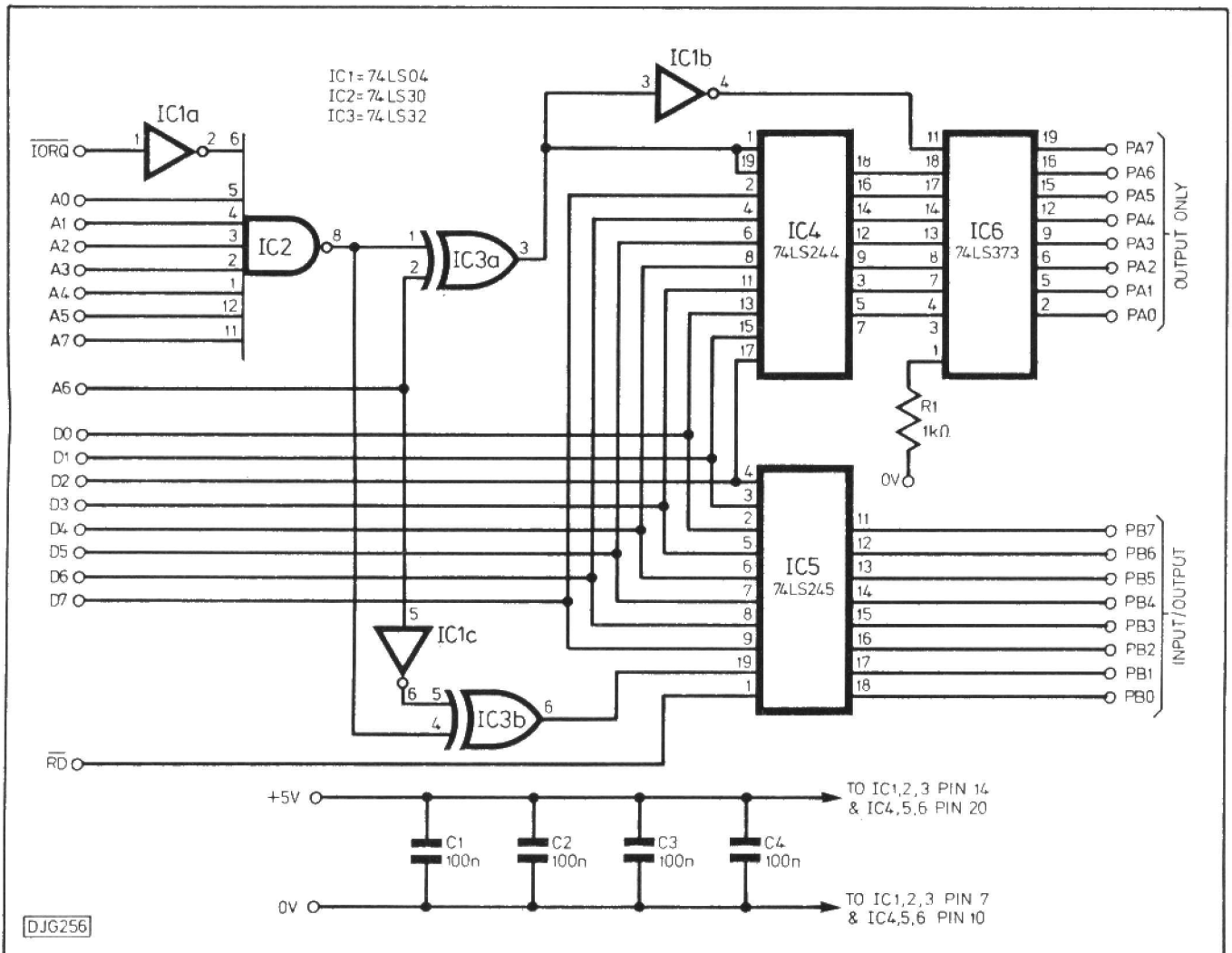
"INGENUITY UNLIMITED"

TWO PRACTICAL INVENTIONS
BY ENTHUSIASTIC READERS

Self Powered Logic Monitor

THIS is a logic i.c. clip monitor that displays the true/false state of each pin of an i.c. by means of l.e.d.s.
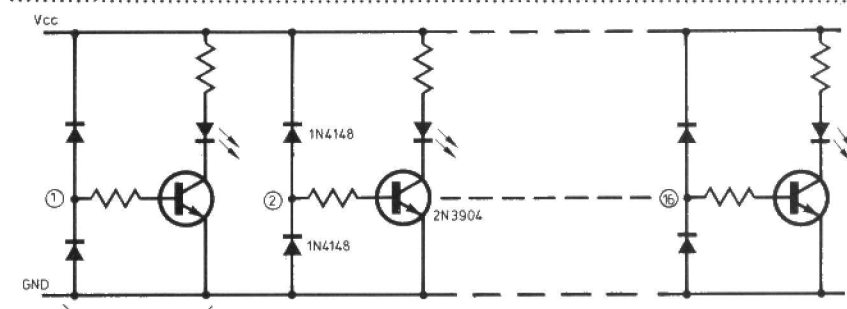
The circuit is self-powered, in that it works out automatically which are the voltage and ground pins, and then draws its power from them. The circuit offers a high impedance to the pins being monitored, and therefore does not affect the circuit being examined. If small l.e.d.s. are used, it is possible to construct the circuit on top of an i.c. clip. Alternatively it can be constructed in a separate box, using ribbon cable for external connections.

This is a useful trouble shooting aid that is more convenient than a logic probe or oscilloscope, since it can be clipped on to an i.c. allowing observation of all the pin states simultaneously. It is suitable for use with the i.c.s. having from 16 to 40 pins.

J.C. Hegter, South Africa.

THIS CIRCUIT IS DUPLICATED FOR EACH PIN, WITH Vcc AND GND BEING COMMON TO ALL PINS.

PE262M
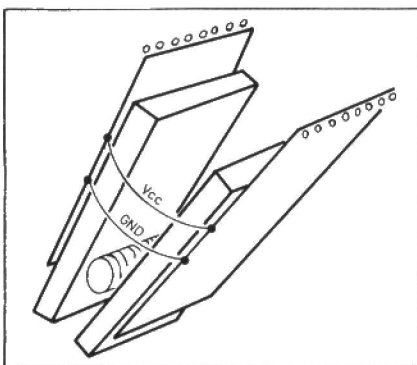
Tachometer

A tachometer is a useful aid when setting up a car engine, and the circuit shown has three ranges: 0-1000 r.p.m. for setting the idling speed; 0-3000 r.p.m. mid-range speeds; 0-10,000 r.p.m. for high speed adjustments.

Pulses from the negative connection of the coil are inverted by Tr1. The series resistor, zener diode and capacitor protect the transistor from high voltages from the coil. The output from Tr1 collector triggers a 555 monostable, the period of which is set by a switchable capacitor and resistor. The output of the monostable is a square wave having a mean d.c. level proportional to the input frequency, and hence the engine r.p.m. This is measured by the meter.

The tachometer may be calibrated by feeding in a square wave from a signal generator at the following frequencies and adjusting the appropriate preset resistor for a full scale reading:

1000 r.p.m. – 33.3 Hz. 3000 r.p.m. – 100 Hz. 10000 r.p.m. – 333 Hz.

These figures are for a four-stroke engine. For a six-stroke engine, multiply the frequencies by 1.5, and by 2.0 for an eight-cylinder engine. For other engines, the calibration frequency may be calculated from the formula:

$$F = N \times r / 120,$$

where N = number of cylinders, and R = r.p.m. To obtain the exact reading it may be necessary to adjust the value of the resistor in series with the preset resistor. A stabilised +8v supply is obtained from the +12v input via a protection diode and 8v regulator. A +5v regulator with a 3v zener diode in its common lead may be used if an 8v regulator cannot be obtained.

K. Wevill, Leicester

PE261M
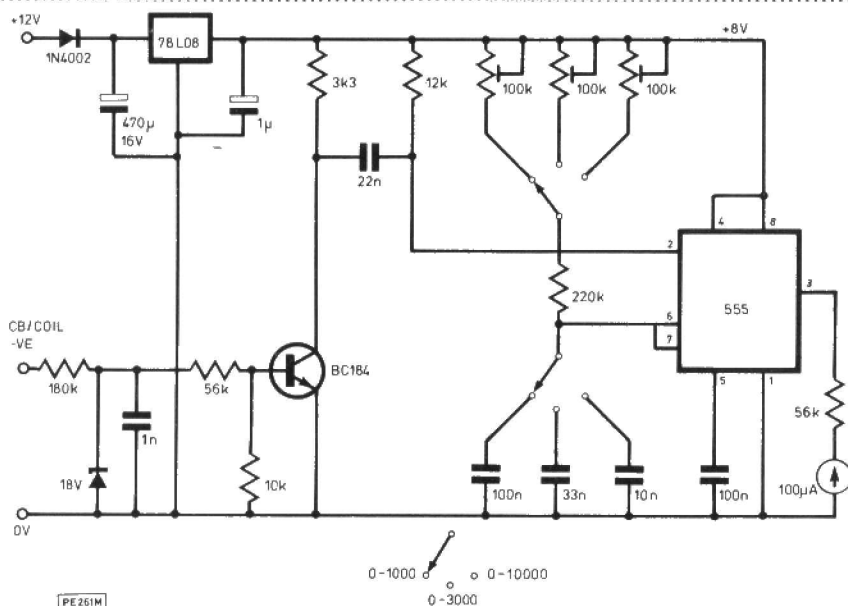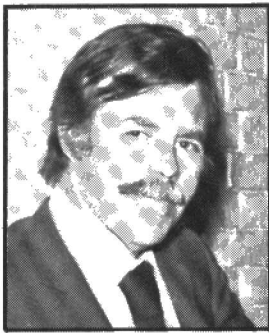
INDUSTRY NOTEBOOK

People's lives and industrial production

Cutting manpower is essential to maintain the cost efficiency of the electronics industries – or is it just an excuse for not taking a hard look at our technical efficiency?

REPORT BY TOM IVALL

As I write this, 550 people in Thorn EMI Electronics Ltd, mainly at Hayes and Feltham, are preparing themselves to be made redundant. A company spokesman recently said: "We are having to make people redundant to remain competitive in business."

This, then, is a further way in which the electronics industry affects our lives – through the livelihoods of those who work in it. I am not singling out Thorn EMI Electronics for special attention: redundancies are common enough these days. Nor am I forgetting that while existing jobs are being abolished in one firm, new jobs are being created in another. The real point is that this industry, like others, has the power to give and take away livelihoods. And, furthermore, it is starting to take its own medicine. Having developed techniques and systems to improve manufacturing efficiency or services in other industries, the electronics industry is now – somewhat belatedly in the UK – learning to apply them to itself.

As the Thorn EMI man said, the overall necessity for a company is to remain competitive. If you fail to do this, other firms, either in the UK or abroad, will eat into your market share – and this applies to both domestic and export markets. To remain competitive, and so survive in business, you have to offer goods or services on the market which are attractive or at least acceptable to that market, at prices which are no higher than those of your competitors and if possible below them. This means that the goods or services must be produced at the lowest possible cost consistent with the level of quality expected by the market.

One way of doing this is to cut production costs by reducing the input of labour required. Then for a given output in sales to the market the money input in wages and salaries is less than it was before. This is the principle behind what the government and others are currently describing as the country's increase in productivity. It is achieved either by the straightforward method of looking for situations of over-manning and correcting these by enforced redundancies, or by the more complicated strategy of re-equipping the factory with new machines or systems that inherently require less labour than before. Obviously both methods can be used together.

In general, productivity is a measure of production efficiency – of a country, an industry, a factory, a process, a system or a machine. Being a measure of efficiency, it is expressed as an input/output ratio. For countries and industries the input is usually reckoned in units of labour and the output in units of product value, or money. For a particular manufacturing activity the product value should strictly be the added value imparted by the production process. This excludes the value of any materials or components used in the process which have already been manufactured elsewhere.

Thus in Britain overall productivity figures are commonly given in the form of pounds sterling per man/woman-hour. With factories or plants the output is more likely to be expressed in units of product quantity, giving a more meaningful productivity value such as so many electronic subassemblies per man/woman-shift.

But labour isn't everything. Productivity can also be measured in terms of capital-input/product-output – showing the efficiency of utilisation of capital investment – or in terms of materials-input/product-output – indicating the efficiency of materials utilisation. Nonetheless labour productivity is the most commonly used measure. First of all labour is needed in all industries. Secondly, it can be easily measured as an input. And thirdly, because the worker is also a consumer, labour productivity may be significant as an indicator of consumption and material standards of living.

Modern automation based on electronics is one of the technological advances that can be used to raise the productivity of a factory, a process or a machine. It increases the proportion of output relative to input. This may mean raising the output, if the demand is there, for a given available input. Alternatively, it may mean decreasing the input when a particular level of output must be maintained – say when the market can't be expanded. In countries where labour is relatively costly, automation tends to be equated with the reduction of man/woman-hours required for input. But in countries where labour is cheap, greater weight is given to the efficient utilisation of the other two main factors of production – capital investment and raw materials.

So automation can increase the proportion of output to input in several ways. With respect to capital, it can give better utilisation of the available capacity of the plant and machinery. Then it can reduce the requirement for materials and cut down wastage in processing. Finally, with respect to labour, automation can give a straightforward reduction in the number of workers required – or perhaps the proportion of skilled, highly-paid workers needed.

In electronics manufacturing there are three main areas where new methods are beginning to be used to improve productivity. The first is the control of last-minute engineering changes made to subassemblies long after the development phase has finished. One well-known electronics company records an average of one such engineering change on each printed-circuit board every six weeks. These changes are bad because they raise costs by increasing lead times, making more work-in-progress and producing a larger inventory. The second problem being tackled is the reduction of unit costs. The third is cutting down the lead times.

Improved manufacturing techniques introduced by the electronics industry have included automatic component insertion machines, construction using surface mounted devices and, more comprehensively, computer integrated manufacturing. The strange thing is that the investment in such new equipment and techniques is usually justified by pointing to savings in the cost of labour input. Yet in the UK electronics industry the cost of direct labour probably averages only 5% or less of unit cost. It might be better all round for the country if the manufacturers worried less about getting rid of workers and concerned themselves more – like the Japanese – with improving the organisation and efficiency of their production.
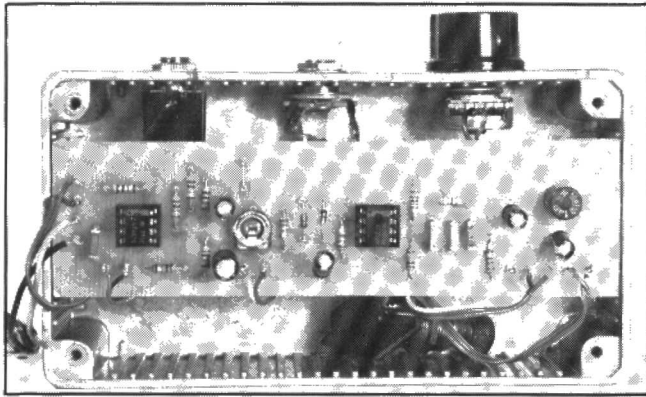
NICE AND EASY DOES IT

BUILDING the projects published in PE is a lot easier than some of you perhaps might think. Especially when you use one of our professionally made printed circuit boards.

It's almost like painting by numbers. All the PCBs are fully drilled, and basically all you need to do is slot in the components and carefully solder them to the PCB track pads. Their places are shown in the drawings published with the project.

IDENTITIES

Component identities are usually clearly marked on them. Even if they are colour coded, like some resistors and capacitors, their values are easily worked out from component colour code charts. From time to time we publish these charts, but if you don't already have one, send a 9in x 4in stamped and self-addressed envelope to the Editorial office asking for one.

TOOLS

For many projects you only need a few simple tools – Soldering iron between 15W and 25W, with a bevelled tip. Damp sponge for keeping the tip clean. Good multicore solder of 18swg or 22swg grade. Fine nose pliers for wire shaping. Adjustable spanner or heavy pliers for tightening nuts. Miniature screwdriver for adjusting preset controls. Small wire cutters for trimming component leads. Drill and selection of bits for drilling holes in boxes. Strong magnifying glass for checking joins in close up. It's also preferable to have a multimeter for setting and checking voltages. There are some very good low cost ones available through many of our advertisers, but get one that is rated at a minimum of 20,000 ohms per volt. Many projects do not require you to have a meter, but if you are serious about electronics, you really should have one.

ASSEMBLING THE PCB

Authors will sometimes offer their own advice on the order of assembly, but as a general guide, it is usually easier to assemble parts in order of size. Start though with the integrated circuit sockets. Please use them where possible, they make life much easier than if you solder the ICs themselves – with sockets you can just lift out an IC if you want.

Then insert and solder in order of resistors, diodes, presets, small capacitors, other capacitors, and finally transistors. Clip off the excess component leads after you have soldered them. Now use a magnifying glass, ideally one that you can hold to your eye, and take a good look at the joins, checking that they are satisfactorily soldered, and that no solder has spread between the PCB tracks and other joins. Be really thorough with visual checking since errors like this are the most likely reason for a circuit not working first time.

SOLDERING

Bring the tip of the iron into contact with the component lead and the PCB solder pad, then bring the end of the solder into contact with all three, feeding it in as it melts. Once sufficient solder has melted to fully surround the pad and the lead, remove the solder, and then the iron. Now allow the join to cool before touching it, otherwise the solder may set unsatisfactorily. If it does move, just reheat the join once more.

WIRING

Connecting the PCB to the various panel controls is the final assembly stage. Do this just as methodically, following the published wiring diagram. You can connect the wires to the PCB in one of three ways. The best is to insert terminal pins into the connecting holes on the PCB, and then solder wires direct to them. Or, pass the end of the wire through the PCB hole, soldering it on the other side. Alternatively, the wire can be carefully soldered direct to the PCB tracking. In all cases first strip the plastic covering off the wire, twist the strands together, and apply solder to them to keep them secure.

TESTING

Now you are ready to test and use the project as described by the author. Components can occasionally fail, but these days it is extremely uncommon, and if you have followed the instructions, been careful with your joins, and bought the parts from a good supplier, you will have the enormous satisfaction of having built an interesting and working unit. It really can be easy if you do it with care.

P.C. BOARDS

Printed circuit boards for certain PE constructional projects are available from the PE PCB Service, see list. They are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £2 per board for overseas airmail. Remittances should be sent to: **PE PCB Service, Practical Electronics, 16 Garway Road, London W2 4NH.** Cheques should be crossed and made payable to **Intrapress.**

Please note that when ordering it is important to give project title, order code and the quantity. Please print name and address in Block Capitals. Do not send any other correspondence with your order.

Readers are advised to check with prices appearing in the current issue before ordering.

NOTE: Please allow 28 days for delivery. We can only supply boards listed here. You may send a photocopy of the Order Form.

TELEPHONE ORDERS (OPEN 24 HOURS)

You can now order your printed circuit boards by telephone, quoting your Access credit number. The number to ring is: 0268 289923. In stock items will be despatched within 24 hours of receipt of order. If you ring out of office hours please state your order, credit card number and address **clearly,** as the order is recorded on an answering machine.

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Power Supply		504–10	£4.70
Amstrad Synthesizer Interface		505–01	£4.77
Rugby Clock Pt-2		504–03	£30.84
"	MAY '85	504–05	£5.93
"		504–06	£11.70
"		504–07	£6.30
"		504–08	£12.60
CBM64 Music Keyboard			
Keyboard	JUNE '85	506–02	£5.19
Main PCB		506–03	£3.90
MTX 8 Channel A to D	JULY '85	507–01	£4.37
Voltmeter Memory Adapter		506–01	£3.90
Envelope Shaper	AUG '85	508–01	£4.11
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SMPSU Stepper		140	£3.90
" Booster		141	£3.90
" Inverter	APR '87	142	£3.90
Inductive Loop Transmitter		143	£3.90
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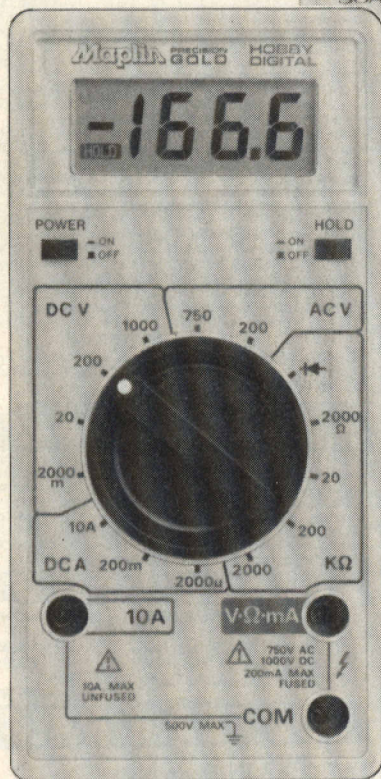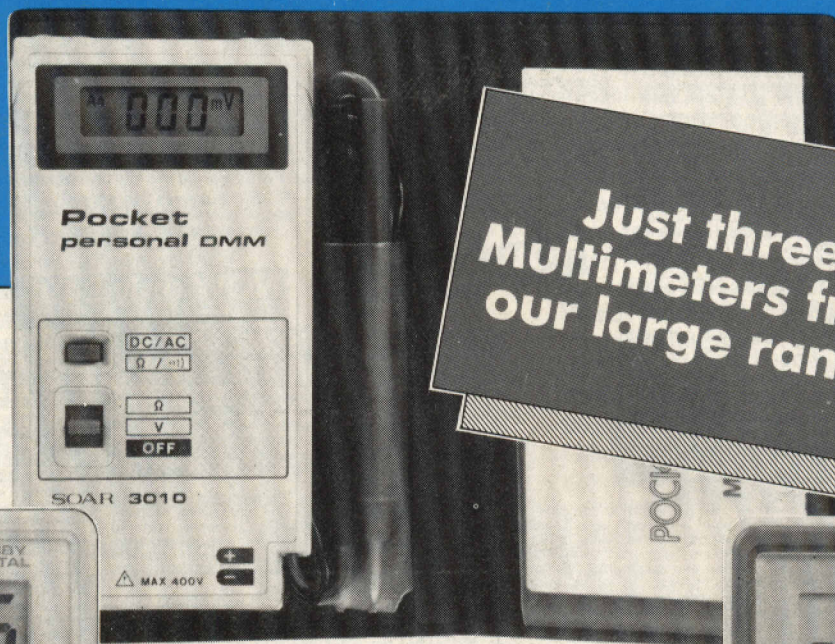
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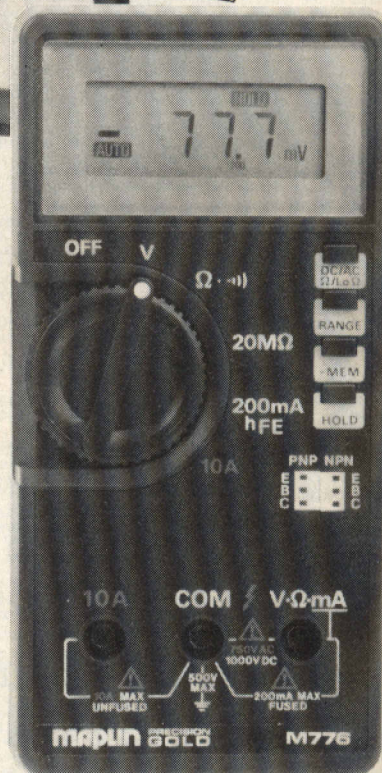
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